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DEVELOPMENT PATH OF FAST POWER REACTORS WITH HIGH BREEDING FACTOR

Moscow ATOMNAYA ENERGIYA in Russian Vol 54, No 4, Apr 83 pp 269-273

BOBROV, S. B., DANILYCHEV, A. V., YEDISEYEV, V. A., ZHUKOVA, O. A., ZVERKOV, Yu. A., ILYUNIN, V. G., MATVEYEV, V. P., MOROZOV, A. G., MUROGOV, V. M., NOVOZHILOV, A. I., ORLOV, V. V., SELESAREV, I. S., SUBBOTIN, S. A., TROYANOV, M. F. and SHAFRYGIN, B. F.

[Abstract] Studies performed in recent years on the improvement of the breeding characteristics of fast neutron reactors have stimulated interest in the use of heterogeneous cores containing both metallic uranium fuel and oxide fuel. These cores may have significant advantages over traditional homogeneous cores with oxide fuel in terms of breeding characteristics. Results are presented in this article from studies of heterogeneous oxide-metal cores, and are used to analyze the variation in basic fuel breeding parameters as functions of the fraction of metallic fuel and the configuration of the internal breeding areas. Studies were performed using various mathematical models of heterogeneous cores. The arrangement of the heterogeneous cores into islands, rings, modules, etc. is insignificant, since it is the increase in the mean density of breeder material in the core which determines the increase in the excess breeding factor. The improvement in breeding factor in such a core depends essentially on the volumetric fractions of fuels. However, the variation in breeding factor as a function of volumetric fractions of fuel is not as strong as in a traditional homogeneous core, allowing optimization of the heterogeneous core from the standpoint of specific fuel load. It is determined that the use of heterogeneous oxide-metal cores is promising to improve the breeding factor of fast-neutron breeder reactors. Figures 4, references 8: 7 Russian, 1 Western.  
[188-6508]

## EXPERIMENTAL DATA ON VVER-400 REACTOR NEUTRON FIELDS

Moscow ATOMNAYA ENERGIYA in Russian Vol 54, No 3, Mar 83 (manuscript receiver 18 Mar 82) pp 200-201

LOMAKINS, S. S., MOROZOV, A. G., PANFILOV, G. G., BONDARS, Kh. Ya. and LAPENAS, A. A.

[Abstract] The authors have measured the neutron field parameters around the core of water-cooled, water-moderated power reactors. Measurements were performed in front of and behind the reactor body and in ionization chamber channels located inside the radiation shield. The activation method was used to determine the fast neutron flux density as well as the spectral parameters and flux density of thermal neutrons. The spectrum of thermal neutrons within the ionization chamber channels in the concrete shield is somewhat harder primarily due to the presence of iron reinforcement in the concrete. Data from different reactors of the same type were essentially identical. A graph of the fast neutron flux density energy distribution of a VVER-440 reactor is presented. Figure 1, references 4 Russian.  
[181-6508]

## PROCEDURAL QUESTIONS RELATING TO USE OF NUCLEAR HEAT-AND-POWER PLANTS IN USSR UNIFIED ELECTRIC POWER SYSTEM AND FUEL AND ENERGY COMPLEX

Minsk VESTSI AKADEMII NAVUK BSSR: SERIYA FIZIKA-ENERHETYCHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 84-89

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[Abstract] Problems relating to the utilization of nuclear heat-and-power plants for supplying heat to cities and industrial centers are of a complex interindustrial nature and special methods have been developed for solving them, which make it possible to arrive at the basic decisions regarding the choice of the equipment profile and of processes for nuclear heat-and-power plants while considering the nuclear heat-and-power plant as an element of the city's heating system. These methods also make it possible to establish for the long term optimal levels of development of nuclear heat-and-power plants, taking into account the requirements of the Unified Electric Power System (YeEES) and fuel and energy complex (TEK) of the USSR. A procedure has been developed, based on the use of methods of system analysis and modern computers, making it possible to select for the next 10 to 20 years optimal scales of development of power and heat generation employing organic and nuclear fuel, the structure of sources of heat, and the system for supplying them with fuel. An analysis is first made of the development of the total heat consumption of cities and

industrial centers for USSR rayons. All cities and industrial centers are grouped within each category of developed heat supply systems, into a combined system, in terms of the relative amount of savings in normalized costs. The heat supply system is regarded as part of the country's fuel and energy complex, taking into account the interrelationship between its parts and respect to the use of various kinds of fuel, as well as part of the YeEES, in view of the operation of nuclear and conventional heat-and-power plants in the electrical load schedule of unified electrical power systems. The problem is solved of selecting optimal levels of development of power and heat generation in the country, and of the use of nuclear heat-and-power plants in the TEK and YeEES in longterm forecasting. Multiple-option studies based on this procedure show that in contrast to fossil-fuel plants, a nuclear heat-and-power plant becomes more efficient beginning with a heat demand of 1600 MW and higher. The optimal percentage for electric power for nuclear heat-and-power plants in the YeEES can reach about 35 percent, as compared with the total output of various types of conventional heat-and-power plants. Under assigned conditions for the development of the USSR TEK, there exists an optimum for the total electrical output of nuclear heat-and-power plants, and deviations from this optimum in one direction or the other result in a considerable increase in normalized costs for the fuel and energy complex. There is no single formally optimal solution for the development of nuclear heat-and-power plants, but a certain range of solutions within which these costs differ but slightly from the minimum. These costs are not affected by a  $\pm 15$  percent variance in the total output of a nuclear heat-and-power plant. Figures 3, references 7 Russian. [146-8831]

UDC: 621.039.50

#### STUDY OF STRUCTURE OF NUCLEAR POWER SYSTEM PROVIDING SATISFACTION OF DEMAND FOR ELECTRICAL AND THERMAL ENERGY

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-ENERHETICHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 80-84

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[Abstract] A description is given of a mathematical model of the nuclear power system, developed at the Institute of High Temperatures, taking into account the specific features of the development of nuclear power in the USSR. All nuclear power plants are divided according to the following features: type of energy produced, i.e., electric or thermal; type of reactor used; and type of nuclear fuel used. Demands for electrical and thermal energy of various potentials to be satisfied by nuclear power are determined as the result of optimization of the overall power system and are used as the initial data for the model. The most important technical and economic characteristics of nuclear power plants with reactors of various types and of enterprises of the external fuel cycle are assumed to be assigned. Constraints on the use of a specific type of nuclear reactor or on reserved of natural raw material at various costs are also assigned as external data. The model is in the form of a system of

linear equations and a linear effectiveness function. The model is dynamic and is calculated for T time intervals for each of which balance equations are written, i.e., balances of the outputs of power-generating plants, balances of material flows between individual elements of the nuclear power system reflecting the internal links with respect to nuclear fuel in it, and constraints on the scales of the entry into service of various nuclear power plants. The type of energy to be produced is used as the major feature in writing the output balance. Equations for output balance in each time interval are written individually for each kind of power medium, and equations are written for groups of consumers with differing levels of concentration of thermal loads, for heat supply plants. The utilization cycle for nuclear power plants is taken into account in terms of mean annual numbers of hours of utilization of their installed capacity, arrived at as the result of studies of the overall power system. The model makes it possible to determine the rational structure for the nuclear power system in terms of types of nuclear power plants, and the influence of technical and economic characteristics of nuclear power plants on the structure of the system, and the total consumption of natural uranium, and also makes it possible to explain how the proportion of the demand for electrical and thermal energy to be satisfied on account of nuclear power can influence the structure of the nuclear power system and the nuclear fuel balance, as well as the level of requirements for individual nuclear power plants, including with regard to the production of secondary nuclear fuel. References 3 Russian.  
[146-8831]

UDC: 621.039.526:516.338.4:621.311.182:629.12

#### STUDY OF NUCLEAR POWER PLANTS WITH FAST GAS-COOLED REACTORS

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-ENERHETICHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 67-73

LESNYKH, V. V., MALEVSKIY, A. L., NAUMOV, Yu. V., POPYRIN, L. S., PROTSENKO, A. N., KNYAZEY, V. A. and SILAYEV, Yu. V., Siberian Energy Institute, Siberian Division, USSR Academy of Sciences; Institute of Atomic Energy imeni I. V. Kurchatov

[Abstract] A solution is given to the problem of combined technical and economic optimization of a single-circuit nuclear power plant with a fast gas-cooled reactor and a gas turbine plant implementing a Brayton cycle with intermediate cooling between compression stages. A software complex, created at the Siberian Energy Institute, including mathematical models of the reactor section and of the thermopower section and a program for computing the thermophysical properties of gases and gas mixtures was used in the study. The model of the reactor section contains algorithms for thermophysical calculation of the core, for a neutron-physics calculation of the core and shields of the reactor, and for determining fuel breeding ratios and technical-economic characteristics of the reactor section. Characteristics of the core and shields of the reactor are described in the most detail, and equipment inside the vessel and the pressure vessel are treated more broadly. The mathematical model of the thermopower



section contains a program for calculating the circuit, which determines the kind of circuit and calculation sequence from the initial data; mathematical models of elements of nuclear power plant equipment, including heat exchangers, turbines, compressors, high- and low-pressure pipelines, electrical equipment and cooling systems; and programs for calculating the thermo-dynamic and technical and economic indicators of the thermopower section; and also a number of auxiliary programs. Various units of the thermopower section are described in varying degrees of detail, depending on the contribution of each element to the variable part of expenditures. Heat exchangers, pipelines and turbine machines are described in the greatest detail. A circuit with two and three compression stages is discussed. The thermopower section equipment includes a turbine, regenerator, final cooler, intermediate coolers, cooling water pumps, a generator with electrical equipment, and a cooling system. Optimization studies were performed for a nuclear power plant with a reactor with a thermal output of 2800 MW with the heat-transfer medium's temperature in the reactor's outlet in the range of 1000 °K, with 250 to 400 °K heating in the reactor and pressure of 16 MPa in the reactor's inlet. Parameters to be optimized for the reactor section were the heat release rate, flattening of the core, and the flowrate of the heat-transfer medium, and for the thermopower section, the pressure behind the turbine, the pressure in intermediate coolers between compression stages, and the flowrate of the gas in the regenerator, final and intermediate coolers and in pipelines. The general conclusion is drawn that it is economically efficient and promising to use an He + CO<sub>2</sub> gas mixture. The use of this mixture as the working medium for a nuclear power plant with fast gas-cooled reactors and a single-circuit gas-turbine plant results in a steady favorable savings. The optimal concentration of the He + CO<sub>2</sub> mixture is 0.214 fractions of total mass or 0.75 mole fractions. The optimal number of compression stages with intermediate cooling is three for all media, i.e., He, CO<sub>2</sub> and an He + CO<sub>2</sub> mixture. Figures 4, references 4 Russian.  
[146-8831]

UDC: 621.039+001.57:621.311.2

# METHODS OF STUDYING OUTLOOK FOR VARIOUS TYPES OF NUCLEAR POWER PLANTS IN EXPANDING NUCLEAR POWER SYSTEM

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-ENERHETYCHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 61-67

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[Abstract] A method of feasibility analysis is presented, which makes it possible to relate the choice of physical and technical characteristics of promising nuclear power plants, i.e., hybrid fusion reactors and molten-salt reactors, to system, i.e., the beginning of quantity entry into service, rate of growth and startup capacities, and economic, i.e., permissible capital outlays, characteristics. This method makes it possible to take into account factors whose influence lasts only a few days, weeks or months, a situation

which is characteristic of the types of promising nuclear power plants discussed. The following two problems are solved: 1) for a specific type of thermal reactor, to indicate the limiting physical and economic characteristics of any producer; and 2) for a specific type of producer, to indicate the limiting physical and economic characteristics of a promising thermal reactor, e.g., a molten-salt or heavy-water. A procedure is presented which makes it possible to make an analysis of the influence of the key physical characteristics of the producer on its economic and full-scale indicators under conditions of joint operation of the producer and consumer in a closed fuel cycle, taking into account system requirements. An analysis is made of various variants of the fuel cycle by creating sufficiently detailed models for obtaining information on the economic competitiveness of various variants of producers for available designs and operating modes. An analysis is made of the influence of delays in commercial startup of various types of producers on the value of functionals of the economic optimization criterion. A simulating model of an expanding nuclear power system is used and the criterion of discounted costs for the production of electric power integrated for the calculation period is used as the global criterion for comparing various strategies and variants. The entire time period for the development of the nuclear power system is arbitrarily divided into four stages. For example, at stage I  $T_1^{BR} > t \geq T_0$ , where  $T_1^{BR}$  is the year of the commercial startup of the fast reactor system and  $T_0$  is the hypothetical year of the start of development of the nuclear power system. At stage II,  $T_1^{GTyAR} > t \geq T_1^{BR}$ ; at state III,  $T_1^{GTyAR} < t \leq T_3^{GTyAR}$ ; and at state IV,  $T > t \geq T_3^{GTyAR}$ , where GTyAR represents hybrid fusion reactors. A thermal reactor + fast reactor + hybrid fusion reactor system is compared with other possible strategies. A molten-salt reactor is considered promising because its conversion factor can reach 0.8 to 0.9 for a uranium-plutonium cycle and even 1.06 to 1.10 for a uranium-thorium cycle. The possibility is mentioned of operation of a hybrid fusion reactor in a symbiotic relationship with a molten-salt reactor whereby the reactors exchange nuclear fuel. Figure 1, references 8 Russian. [146-8831]

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#### PROCEDURE FOR ESTIMATING POTENTIAL ROLE OF BREEDER IN ENERGY OF FUTURE

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-ENERHETYCHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 56-61

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[Abstract] A simplified model of a multiproduct nuclear power system is presented by means of which it is possible to make an economic estimate of the potential role of various kinds of breeders within an optimization framework. A search for an economical variant of a breeder is made at the same time as optimization of the characteristics of each type of breeder in terms of a system criterion,

with consideration of the economic value of the breeder's breeding properties and possible changes in the cost of constructing and using the unit and of external fuel cycle enterprises for it, caused by the speedup of breeding. The percentages of various types of reactors are sought in an optimization formulation, taking into account not only the balance of fuel in the system, but also possible differences in the cost of constructing and using fuel cycle plants. A model of a multiproduct nuclear power system is considered for the purpose of correctly determining the place of various kinds of reactors. As the result of a preliminary estimate of the development prospects for the energy system, a determination is made of possible output by nuclear power of energy products of various kinds, including electric power under base load and semipeak conditions, various kinds of production-process heat and the like. It is assumed that it is potentially possible to develop a nuclear power system on the basis of a given number of various types of nuclear power plants, each of which can product one or more kinds of energy product or just nuclear fuel. The problem is formulated as follows: of the available large number of plants, to choose those which will make it possible to fulfill the assigned production plans for various kinds of energy with minimum input of money for the nuclear power system as a whole. The characteristics of all plants to be compared must be chosen by taking into account system constraints. The value of routine expenditures for the nuclear power system as a whole is used as the cost criterion for comparing options for development of the system under conditions of constancy of the exponential rate of growth of the nuclear power system and of its structure. By means of the model used for describing the fuel balance, it is possible to take into account correctly differences in time delays for fuel in various areas and in the external cycle, as well as the multi-isotope nature of the secondary fuel circulating in the system. It is shown that the role of any individual plant in the nuclear power system can be characterized completely by two generalized indicators. The first is an indicator of breeding of the fuel in the reactor taking into account its operation in a nuclear power system developing at a specific rate. The second indicator is an economic indicator showing what the cost would be of the nuclear power system if it consisted entirely of plants of a given type. By using these two generalized indicators the problem is reduced to a problem in linear programming with an insignificant number of constraints. The simplicity of the model developed makes it possible to determine the optimal percentages of various kinds of plants at the same time as making a determination of the optimal parameters of a plant.

References 6 Russian.

[146-8831]

## ANALYSIS OF POTENTIAL CAPABILITIES OF ALTERNATIVE BREEDERS IN MULTICOMPONENT MODEL OF NUCLEAR POWER SYSTEM

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-ENERHETYCHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 51-56

ILYUNIN, V. G., MUROGOV, V. M., RUDNEVA, V. Ya., SHMELEV, A. N. and KOROVIN, Yu. A., Energy Physics Institute, Obninsk; Moscow Engineering Physics Institute; Obninsk Branch, Moscow Engineering Physics Institute

[Abstract] Under discussion currently are the possibility and feasibility of using in a nuclear power system of the future alternative breeders which are producers of secondary nuclear fuel, including hybrid fusion reactors and electronuclear plants. It is expected that the introduction of producers of this sort will make it possible to reduce to a minimum the percentage of breeders which are more expensive than thermal reactors, and at the same time to improve the structure of the system of producers of nuclear power, as well as to bring it into accord with the structure of consumers. A theoretical comparison is made of indicators of variants of a model of a nuclear power system using various kinds of alternative breeders. A procedure described in an earlier study (1981) for a system analysis of the role and indicators of breeders is extended to the case of a multicomponent model of a nuclear power system expanding with an external source of nuclear fuel, i.e., mined natural uranium or secondary nuclear fuel produced in hybrid fusion reactors or electro-nuclear reactors specially designed for this purpose. A procedure is presented for analyzing the indicators of the model of the nuclear power system. It is assumed that the system consists of fast and slow reactors and is in a steady period of development, whereby the additional entry of fuel into the system is possible. For the purpose of estimating the effectiveness of various variants of the model, a functional is introduced which characterizes the cost of the electric power produced in the nuclear power system. This functional depends on the ratio of the output of fast and slow reactors, the additional contribution of the fuel source, and individual economic indicators for each type of plant. The expression derived for comparative analysis makes it possible to eliminate from consideration the question of the cost of the intermediate product--the secondary nuclear fuel--and to be restricted to using relative ratios of the total cost of plants of various types, making it possible to facilitate considerably analysis of the effectiveness of various variants of nuclear power systems. By means of the approach used to analyzing the characteristics of breeders, it is possible to determine the value of improving various parameters of fast and slow reactors, hybrid fusion reactors and electronuclear plants, and to study the influence of various factors on these indicators, i.e., of the internal structure of the models of nuclear power systems under discussion. Three key variants of a multicomponent model of an expanding nuclear power system with reactors of various types were considered: 1) without replenishment of a closed nuclear power system from an external source; 2) with replenishment of the system with nuclear fuel from a special-purpose producer that does not put electric power into the system; and 3) with replenishment of the system with nuclear fuel from a producer (a breeder) that does put electric power into the system. Calculations

were performed by using a water-cooled reactor of the VVER-1000 type as a slow reactor and two types of fast reactors, of the BN-1600 type with liquid metal cooling utilizing  $\text{PuO}_2\text{-UO}_2$ , and one employing metallic fuel. Indicators for alternative breeders, electronuclear plants, and hybrid fusion reactors, for the rate of production of nuclear fuel and the percentage of electric power produced by them, and the ratio of total costs for various types of plants, varied over a wide range. It was found that over a wide range of variation of required rates of development, the introduction into the structure of a nuclear power system of alternative breeders makes it possible to reduce the required percentage of fast reactors in the system by 10 to 30 percent and to increase the relative percentage of slow reactors, i.e., nuclear reactors with the lowest total cost, to 60 percent and more. However, the introduction of a special-purpose producer not producing energy for the nuclear power system results in an increase in total costs per 1 MW of power produced in the system. The way out of this situation is to improve the conversion indicators of fast reactors by using improved types of fuel, primarily metallic. Also, the competitiveness of alternative breeders is improved considerably if they produce electric power or production-process heat in addition to fuel. The estimates arrived at make it possible to determine the cost areas for possible competitiveness for optimistic variants of nuclear power plants with an electronuclear plant or a hybrid fusion reactor. Figures 1, references 8: 5 Russian, 3 Western.  
[146-8831]

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OPTIMIZATION MODEL OF DEVELOPMENT OF WIDESCALE NUCLEAR POWER, INCLUDING PRODUCTION OF ELECTRIC POWER AND HEAT

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-ENERHETYCHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 47-51

YELAGIN, Yu. P., Institute of Atomic Energy imeni I. V. Kurchatov

[Abstract] In forecasting the development of nuclear power for the longterm it is important to have models making it possible to make a quantitative estimate of the influence of the large-scale development of heat-producing and steam-producing nuclear power and other kinds of nuclear power on the structure of the nuclear fuel complex as a whole. A description is given of a linear optimization model of an expanding nuclear power system with a complex structure including various applications of nuclear power in the economy. The optimality criterion is a minimum of reduced expenditures for development of the nuclear power systems and an appropriate fuel base in a specific time interval with provision for a specific plan for the generation of various kinds of energy at nuclear power plants. Expenditures for the development of a nuclear power system with an optimal structure are minimized by sampling types of nuclear power plants from a given list, to be put into service at various times within the forecast period. Constraints are determined by balances for the production of the various kinds of energy, the recycling of fuel in the nuclear power system,

the size of reserves of natural uranium at various costs, and in the degree of preparedness of industry to produce energy equipment. Balances are summed for the country or for a large region as a whole. Linear programming is used to solve the optimization problem. For the sake of simplifying the model, the description of the fuel cycle of nuclear power plants of various types is unified by replacing real systems for admission of fuel to the reactor and its subsequent unloading by ideal ones and by introducing effective fuel constants. Expenditures for a system of nuclear power plants to be put into service in a specific time segment are made up of capital expenditures for construction, additional expenditures for retooling entailed in changing the operating mode or kind of fuel, routine expenses, the fuel component of expenses, and expenses for removing a plant from service at the end of its life. Calculations performed according to the model described demonstrated that the elasticity of a nuclear power system turns out to be considerably less than in the case when this system is entirely an electric power producing system. The energy rapidly becomes more expensive in proportion to the depletion of deposits of uranium with a low mining cost. A promising way to improve the economic efficiency of a nuclear power system is to improve its heat-producing part. Economical nuclear heat-and-power plants based on fast breeders should be developed. The fuel cycle of both nuclear electric power plants and of nuclear heat supply plants should be improved considerably. References 2 Russian.  
[146-8831]

UDC: 621.039.9.621.311.1

# INFLUENCE OF SYSTEM FACTORS ON DEVELOPMENT TRENDS AND KEY PARAMETERS OF NUCLEAR POWER PLANTS

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-ENERHETYCHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 42-46

LEVENTAL', G. V. and KIT, V. S., Institute of High Temperatures, USSR Academy of Sciences

[Abstract] System factors are defined as factors expressing the requirements for the technical and technical-economic characteristics of nuclear power plants of various types and which result from the conditions for the effective development of power systems. Studies have been made of the development of the nuclear power system as a subsystem of the overall energy system, which consists in turn of subsystems for the utilization of nuclear fuel and heat supply. The number of types of nuclear power plants has increased in the process of satisfying the demand for thermal energy, so that now there are not only nuclear condensation power plants (AKES's), but also nuclear power-and-heating plants (ATETS's) and nuclear heat supply plants (AST's). The development of AKES's and ATETS's as elements of the country's electric power systems should be studied in terms of structural problems for these systems. It is shown how system factors are formed which influence the development trends for nuclear power plants, including for various types of nuclear power plants and nuclear sources of heat. System factors include: 1) The ratio of the percentages of nuclear



and organic fuel in the country's total demand for energy resources. This factor is under consideration at the level of the total energy system, and it specifies the integral quantities of electrical and thermal output of nuclear power plants. 2) Rates of growth of the consumption of nuclear fuel for electrical supply and heat supply purposes. This factor is considered on the level of a nuclear power system and specifies the requirements for converting to a closed fuel cycle and for the development of nuclear power plants with breeder reactors. 3) Longterm capacities of nuclear heat supply sources for various regions of the country. This factor is considered at the level of local power supply systems, including heat supply systems, of industrial centers and cities, and specifies the appropriate scales for the development of the capacities of ATETs's, AKES's which supply heat and AST's for various regions of the country. 4) The share of nuclear power plants in the structure of the capacities of electric power systems, taking into account participation in satisfaction of heat demands. This factor is considered at the level of electric power systems for key regions of the country and specifies the scales and proportions of capacities of AKES's with various equipment characteristics, as well as of ATETs's, and validation of modes for utilizing them. References 6 Russian.  
[146-8831]

UDC: 621.311.25:621.039.319.86

#### EXPERIENCE AND PROBLEMS OF STUDYING NUCLEAR POWER PLANTS IN NUCLEAR POWER SYSTEM AND IN ELECTRIC POWER SYSTEMS

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-ENERHETYCHNYKH NAVUK in Russian No 4, 1982 (manuscript received 17 Mar 82) pp 38-42

POPYRIN, L. S., Energy Institute imeni G. M. Krzhizhanovskiy

[Abstract] Nuclear power plants are discussed in the context of the nuclear power system, electric power systems and heat supply systems, where they are regarded as the point of intersection of these systems. The nuclear power system includes enterprises for the production of nuclear fuel, separate plants for enrichment of uranium, enterprises for producing fuel elements and shields, nuclear power plants and the spent fuel processing industry. Conditions affecting the development of the nuclear power system exert a decisive influence on basic decisions relating to nuclear power plants. Conditions for the development of electric power systems govern requirements for the unit output of a nuclear power plant and its basic units, the choice of sites for building nuclear power plants, and the modes of utilizing them, and many other factors. Heat supply systems make demands on nuclear power plants with respect to the tapping of heat, the kind of heat-transfer medium and its parameters, and heat consumption cycles. Decisions relating to the country's fuel and energy complex stipulate the longterm strategy for the development of nuclear power and determine the percentage of nuclear fuel in the fuel and energy complex. This in turn influences the choice of the optimal structure for a nuclear power plant and the requirements for its neutron-physics and energy characteristics. Consideration of a nuclear power plant as the subject for feasibility and optimization studies must take into account the fact that a nuclear power plant has

certain features which complicate the process of solving the problem. These include the influence of thermophysical characteristics of the reactor on the required quality of the nuclear fuel and the fact that nuclear power plants are multipurpose plants. The only possible approach to solving problems relating to technical and economic optimization of a nuclear power plant is the methodology of system research with mathematical modeling as the most important tool used. The great number of problems which must be solved in selecting the type, parameters and profile of a nuclear power plant's equipment makes it necessary to use not a single mathematical model, but an interrelated hierarchical system of mathematical models. A possible structure for this system of models is presented. Although definite achievements have been made in systems studied, many methodological problems have not been solved or have been solved incompletely. It is necessary to improve mathematical models considerably in the direction of more complete reflection of actual processes in power systems, with respect to constraints relating to the supply of labor, material and financial resources. It is necessary to take into account more fully the ecological aspects of developing a nuclear power system, in order to evaluate the effect of various development strategies on the environment. Studies must be aimed at improvement of the utilization of nuclear fuel in nuclear power plants, at the development of alternative methods of making secondary nuclear fuel, including gas-cooled fast breeder reactors and hybrid fusion plants, the creation of nuclear reactors with a smaller content of construction materials in the reactor, and the creation of nuclear power plants with fuel elements which withstand repeated loading and have various kinds of heat accumulators. A method must be developed to convert long-living radioactive fragments into short-living and stable isotopes. Figures 2, references 12 Russian.

[146-8831]



NON-NUCLEAR ENERGY

UDC: 662.997:537.22(088.8)

DESIGN OF BATTERIES WITH SOLID FILLERS

Tashkent GELIOTEKHNICA in Russian No 2, Feb 83 (manuscript received 2 Mar 81)  
pp 53-55

POZ, M. Ya., KOGAN, D. Ya. and AVEZOV, R., Tashkent Zonal Scientific Research  
Institute of Experimental Planning of Residential and Public Buildings

[Abstract] An equation system is derived for the process of heat exchange between a solid filler and air moving horizontally through the calculation volume which contains a vertical barrier of the filler. A computer program has been written to perform the calculations. Graphs are presented showing the change in air temperature at the outlet of a battery for various values of characteristics. Figures 3.

[186-6508]

UDC: 621.472

ECONOMIC ANALYSIS OF COSTS OF INSTALLATION AND ADJUSTMENT OF SOLAR POWER-PLANT  
HELIOSTAT FACETS

Tashkent GELIOTEKHNICA in Russian No 2, Feb 83 (manuscript received 30 Apr 82)  
pp 40-42

ZAKHIDOV, R. A., BOGDASAROV, V. M. and KLYCHEV, Sh. I., Central Planning-Design  
and Technological Bureau of Scientific Instrument Building, UzSSR Academy of  
Sciences

[Abstract] The problem of optimizing the design and installation of the facets of a heliostat can be attacked in two ways: 1) improvement of the fastening and adjustment units of the facets for existing methods of adjustment; 2) development of new methods, for example installation and adjustment under factory conditions with special high productivity stands or elimination of adjustment by increasing facet size and accuracy of manufacture of the load-bearing frame. The operations involved in installation of facets are analyzed. Time and motion analysis indicates that the cost of installation and adjustment

of facets by trained workers is 1.04 rubles per facet at today's wages and using today's equipment. This represents 2 to 3% of the total cost of a heliostat, indicating that the major factor which must be considered to determine the desirability of superior designs is time expenditure rather than money. References 4 Russian.  
[186-6508]

UDC: 621.472

#### INFLUENCE OF HEAT EXCHANGE FACTORS ON RESULTS OF SOLAR POWER SYSTEM THERMAL OPTIMIZATION

Tashkent GELIOTEKHNIKA in Russian No 2, Feb 83 (manuscript received 28 Sep 82)  
pp 37-40

TEPLYAKOV, D. I. and APARISI, R. R., State Scientific Research Energy Institute imeni G. M. Krzhizhanovskiy

[Abstract] A comparison is presented of the results obtained by thermal optimization of a solar powerplant utilizing saturated water vapor by various calculation models. The calculations show that the primary equipment of a tower type solar powerplant can be significantly improved by designers to reduce the cost of optical systems and automatic control equipment without significantly reducing the power effectiveness of the system as a whole. During planning of such systems, some excess solar concentrating capacity should be included to compensate for such output-reducing factors as the formation of scale. Figure 1, references 4 Russian.  
[186-6508]

UDC: 662.997

#### EXPERIMENTAL STUDY OF EFFICIENCY OF TRANSPARENT FILM TEMPERATURE SENSORS STRUCK BY SOLAR RADIATION OF VARIOUS CONCENTRATIONS

Tashkent GELIOTEKHNIKA in Russian No 2, Feb 83 (manuscript received 8 Jun 82)  
pp 33-36

MAVASHEV, Yu. Z., TRESKIN, S. A., AVGUSTINOVICH, I. G., RUDSHTEYN, V. L., deceased, SALIKHOVA, F. S. and ARUSHANOV, G. M., Institute of Physics and Technology imeni S. V. Starodubtsev, UzSSR Academy of Sciences

[Abstract] A study is presented of the properties of transparent film temperature sensors when struck by concentrated high density solar radiation. The change in their resistance under these conditions is determined. Specimens of film were studied on an installation consisting of a multifaceted concentrator, heliostate, coordinate device, specimen holder and measurement system. The time of irradiation of the specimens with fluxes of various densities was

about 15 minutes. The resistance of the specimen, radiometer signal and actinometer signal were measured. Testing of the specimens revealed the limits of radiant energy flux density at which the sensors yield stable indications. Specimens with  $\text{In}_2\text{O}_3$  films were more resistant to radiation than specimens with phosphide films. The most resistant  $\text{In}_2\text{O}_3$  specimens could tolerate up to  $3000 \text{ kW/m}^2$  of incident radiation. Figures 2, reference 1 Russian.  
[186-6508]

UDC: 662.997:621.317

#### MULTISECTIONAL FLAT REFLECTORS AS SOLAR RADIATION CONCENTRATORS

Tashkent GELIOTEKHNIKA in Russian No 2, Feb 83 (manuscript received 17 Dec 81)  
pp 25-29

GRILIKHES, V. A. and ZAYTSEV, O. F., Leningrad

[Abstract] An estimate is presented of the energetic and geometric characteristics of flat foclines, reflectors consisting of flat sections, each of which reflects the incoming solar radiation just once. They are compared with low potential solar concentrators of other types to develop preliminary practical recommendations for systems of this type. The optimal degree of concentration of solar energy by these reflectors is 3 to 7. They are comparatively easy to manufacture and are quite useful for low potential solar energy concentration installations. Figures 2, references 6: 5 Russian, 1 Western.  
[186-6508]

UDC: 662.997(02)

#### POSSIBILITY OF ACCUMULATING SOLAR RADIATION IN ORGANIC PHOTOISOMERS

Tashkent GELIOTEKHNIKA in Russian No 2, Feb 83 (manuscript received 14 Jan 82)  
pp 21-24

TRUSHEVSKIY, S. N., YAROVY, S. S., ZEFIROV, N. S., SIDOROV, P. P., GAYDAR, M. I. and PROSKURINA, M. V., All-Union Order of Labor Red Banner Scientific Research Institute of Power Sources

[Abstract] A basically new approach to the accumulation of solar energy is the use of photochemical reactions. Studies have shown that photochemical valent isomerization can be used to accumulate up to  $1300 \text{ kcal/kg}$  of energy, as opposed to  $50 \text{ kcal/kg}$  which can be stored by warming water,  $3740$  by burning of cellulose and  $11,000$  by burning of hydrocarbons. The efficiency of photochemical batteries in terms of utilization of the active portion of the solar spectrum can theoretically be increased to 90%. A number of processes are noted as promising in this respect, including valent isomerization of norbornadiene or its derivatives to quadracyclane. Another interesting system is cyclopentadiene-dihomocubane. Experimental reports indicate the possibility of implementing this method of accumulating solar energy. References 9: 1 Russian, 8 Western.  
[186-6508]

UDC: 62-501.72:61

METHOD OF STIPULATING STRUCTURAL SCHEMES OF MANIPULATORS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 2, Feb 83 (manuscript received 7 Apr 82) pp 147-148

FILIPPOV, O. A., graduate student

[Abstract] Optimization of manipulator mechanisms according to any criterion involves not only kinematic but also structural parameters. Therefore, kinematic synthesis must apply to a multitude of structures. Here a method of automatic stipulation of structural schemes for optimization on a digital computer is proposed, a method based on representing structural schemes by a digital code. Each digit identifies a type of kinematic pair (e.g., 0- oscillator, 1-rotational, 2-translational) and the number of digits in the code corresponds to the number of kinematic pairs in a structure. The number of possible structural schemes is determined according to the relation  $S_{\max} = p^W$  (p-number of kinematic pairs, W- number of manipulator's degrees of freedom). All possible values of the digital analog can be calculated upon conversion from decimal to base-p code. The mathematical model of a manipulator for design optimization by this method is put in a matrix form convenient for computations. Figure 1.  
[175-2415]

UDC: 621.914.06-529

EFFECTIVENESS OF USING ADAPTIVE CONTROL SYSTEMS FOR METAL-CUTTING MACHINE TOOLS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 2, Feb 83 (manuscript received 11 Jan 82) pp 110-114

DODONOV, V. V., candidate of technical sciences

[Abstract] Productivity of a metal-cutting machine tool with adaptive control is defined in terms of time lost in idling and in off-cycle operations (tool setting, inspection) relative to the useful processing time. Modern metal-cutting machine tools with adaptive control operate either in the stabilization or self-adaptation mode or in the optimization mode. Here the expediency and

the feasibility of improving the productivity are examined in the most conventional case of adaptively controlling the dynamic tool adjustment through regulation of the feed rate. The analysis is based on relations between cutting process parameters, feed stroke and depth of cut, and the increment of productivity attributable to adaptive control of the process under various operating conditions. Calculations reveal that adaptive control will be effective when without it the sum of idle time and off-cycle time is longer than or at least equal to the useful processing time. This is demonstrated on a milling cutter for machining a link of a steering drive. The feasibility of achieving higher productivity is determined by the feed rate variation cycle for minimum tool bluntness corresponding to minimum hardness of the removable material and for maximum tool wear corresponding to maximum hardness of the removable material. Figures 2, references 2 Russian.  
[175-2415]

UDC: 621.9.067

#### SELECTION AND CALCULATION OF BASIC PARAMETERS OF TONGS FOR PORTAL-TYPE AUTOMATIC MANIPULATORS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 2, Feb 83 (manuscript received 22 Mar 82) pp 106-109

USOV, B. A., candidate of technical sciences, docent, and IGNAT'YEV, A. A., graduate student

[Abstract] Portal-type manipulators have been developed for automatic transporting of parts such as shafts to and from machine tools in a production line, with either stiff or flexible coupling. Such a manipulator consists of a rail bar above the bench along which a carriage with two feeder arms moves, each equipped with a special tong for holding the processed piece. In driven tongs a piece is gripped and released by action of a drive mechanism, in open tongs a piece is held by its own weight. The design of driven tongs involves calculation of the necessary clamping force in two basic modes of operation: 1) during motion of the carriage both the weight of the piece and the inertia force act in a plane perpendicular to the axis of the piece (shaft) so that the latter is held by the jaws with limited involvement of friction forces; 2) during motion of the carriage the inertia force acts parallel to the axis of the piece (shaft) so that the latter is held by the jaws with substantial involvement of friction forces. Calculations are shown for a tong consisting of two V-groove prism jaws facing each other symmetrically. The holding force depends on the V-angle of the jaws and on the angle which the direction of motion makes with the vertical, also on the acceleration in the direction of motion and its magnitude relative to the tangential component of gravitational acceleration. Stable positioning of the piece and higher maximum permissible acceleration can thus be attained by optimization of these two angles. Figures 3, references 2 Russian.  
[175-2415]

## OPTIMIZED SYNTHESIS OF GUIDE MECHANISM WITH CONSTRAINTS ON CONTOUR VELOCITY IN TEMPLATE-ROLLER PAIR

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 15 Jun 81, after completion 21 Dec 81) pp 55-61

BLEKHMEN, M. D. and POLYKHIN, V. P., Moscow

[Abstract] A roller mechanism for copying a plane contour such as that of a shoe sole from a master template is designed so as to satisfy the basic technological constraints and product quality requirements. Accordingly, the velocity of the tool relative to the contour and the pressure angle between roller and template must both remain within certain ranges, between respective upper and lower limits. Processing of various shapes and sizes must be feasible with the minimum number of mechanism readjustments. The problem of analysis is solved by an approximate parametric description of the contour in terms of two periodic functions, with the aid of cubic splines yielding a continuous curve with smoothly varying curvature, so that the coordinates as well as first and second derivatives can be determined uniquely at any point. Contour velocity and pressure angle are calculated on this basis. The problem of synthesis is solved as an optimization problem, with reliability and life added as performance parameters. The corresponding search algorithm yields the necessary design parameters. The procedure is demonstrated on the design of a mechanism used for processing left and right mens' shoes, womens' shoes, and school shoes. Figures 3, tables 2, references 5 Russian.  
[170-2415]

## SYNTHESIS OF ALGORITHM OF MANIPULATOR MOTION CONTROL ACCORDING TO GIVEN TRAJECTORY BASED ON DYNAMIC MODEL OF SERVOMECHANISM

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 5 Jun 81, after completion 11 Feb 82) pp 50-54

VOROB'YEV, Ye. I. and PIS'MENNAYA, Ye. V., Moscow

[Abstract] An algorithm is synthesized for controlling the motion of an automatic manipulator through a servomechanism. In the case of an industrial robot the servomechanism is much heavier than the load and, therefore, an algorithm on the basis of a dynamic model is required. The corresponding equations of motion, for the servomechanism in generalized coordinates and for the tong in Cartesian coordinates, are solved for a given curvilinear tong trajectory defined in the form of an integral manifold. The problem is to first construct differential equations for the manipulator accordingly so that the manifold describing the trajectory will, indeed, be the integrals of these equations and then determine the control actions as well as control parameters and relations

which will ensure motion of the system under given constraints. The solution is demonstrated on motion of the tong from point  $x_0$  to point  $x^f$  along the trajectory  $\varphi_1(x_1, x_2, x_3) = 0$ ,  $\varphi_2(x_1, x_2, x_3) = 0$  under the constraints  $x(t=0) = x_0$ ,  $\dot{x}(t=0) = 0$ ,  $\dot{x}(t=\infty) = 0$ ,  $x(t=\infty) = x^f$ ,  $\dot{x}(t=\infty) = 0$  according to the program  $x_1^* - x_1(t) = c_{11}e^{a_{11}t} + c_{12}e^{a_{12}t}$  ( $x_1^*$  - solution to the system of equations describing the trajectory at fixed  $x_1$ ,  $x_1(t)$  - instantaneous coordinates of the tong,  $i = 1, 2, 3$ ). The algorithm was tested for this case on a digital computer by simulation of a rectilinear trajectory and found to be accurate within 1% of the length of moving elements with a response time of 0.2 s, more accurate than an algorithm based on a kinematic model when the transient period is longer. Figures 3, references 8 Russian. [170-2415]

UDC: 621.01

#### COMPUTER MODELING OF HYDRAULIC DRIVES WITH INERTIALESS ELEMENTS

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 4 Sep 81, after completion 24 Mar 82) pp 41-46

YERMAKOV, S. A. and KUDINOV, A. V., Moscow

[Abstract] A mathematical model of multielement hydraulic power drives has been developed for description and analysis of processes occurring in them. Its basic concepts are demonstrated on an industrial throttle-type linear-motion hydraulic steering mechanism and its nine functional components: cylinder, distributor, throttle in intercavity flow channel, valve (globe, safety), summator, feedback mechanism, mechanical link from piston to common output element, mechanical link from common output element to load. A schematic diagram is drawn interconnecting the components in a single-channel version, several modes of connection being considered, and a computer program is devised for calculating the response to a load perturbation such as a unit-step signal on the basis of the corresponding equations of motion and  $p$ - $Q$  (pressure - flow rate) relations. Calculations are based on the finite-difference approximation of derivatives and interpolation by the Newton method, with subsequent integration according to the fourth-order Runge-Kutta scheme. A typical calculation of the transient response on a YeS-1030 Unified System digital computer requires 10 min of machine time and yields results in close agreement with experimental data. Figures 3, references 4: 2 Russian, 2 Western. [170-2415]

## MAIN RESULTS OF STUDY PERTAINING TO DYNAMICS OF CONSTANT-SPEED PULSE MECHANISMS

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 22 Sep 81, after completion 30 Aug 82) pp 13-15

KARABAN', V. G. and SKREBTSOV, A. I., Volgograd

[Abstract] A constant-speed pulse mechanism for automation of manufacturing processes consists of a variable transmission acting as power drive with feedback through a tachometer, a comparator, and a servomotor. The variable transmission ("variator") includes a converter, a controller, idlers and intermediate gears. The dynamics of such a mechanism were studied both theoretically and experimentally. The theoretical study was based on a mathematical model for each component of the closed-loop system, namely equations of motion for a centrifugal tachometer coupled to a hydraulic slide valve, for a servomotor, and for a pulse-type variator with idler clutches. The variator had to be considered in two modes of operation: forced motion with all clutches engaged and free motion with all clutches disengaged. The mathematical model covered also the transient response to perturbation of any form, with variable speed of driver shaft and variable torque on follower shaft. The equations were solved by numerical methods on a computer. The equipment for experimental study included a DS 541/4 N balance-beam dynamometer, a fluidic auxiliary automation system, an electric power supply, a control system, a dynamometer-variator programmer, and a measuring system including strain gauges, phase and displacement transducers, pressure gauge and thermometer, manometer, ammeters, voltmeter and oscillograph. The experimental data were processed on YeS-1020 and YeS-1022 Unified System computers. In this study were calculated and measured the response to harmonic perturbations as a function of time, maximum speed deviation as a function of the perturbation frequency, and maximum average transient torque as a function of the perturbation frequency and amplitude. There was close agreement between theoretical and experimental results. Figures 6, references 3 Russian.  
[170-2415]

## CALCULATING PARAMETERS OF ADAPTIVE INDUSTRIAL ROBOT IMAGE CONVERTER OPTICAL SYSTEM

Leningrad IZVESTIYA VYSSHIKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian No 3, Mar 83 (manuscript received 15 Apr 81) pp 90-95

KOMAROV, V. M., Rybinsk Institute of Aviation Technology

[Abstract] Solid state optical image converters can be installed directly on the actuating unit of an adaptive industrial robot. This allows a change in the zone of vision as a function of the dimensions of the objects to be manipulated,



assuring constant relative error in the measurement of parameters. Equations are derived for selection of the parameters of such an optical system to assure that the information needed to control the robot will be received without supplementary adjustment regardless of the size of the zone of vision required. An equation is produced which defines the minimum resolution of the lens required for the system to operate properly. Figure 1, references 5 Russian.  
[179-6508]

HEAT-PIPE COOLING SYSTEMS FOR BLADES OF GAS TURBINE ENGINES

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 1, Jan 83 (manuscript received 22 Feb 82) pp 87-92

KOMAROV, B. I., engineer, BARANOVSKIY, B. V., candidate of technical sciences,  
and MANUSHIN, E. A., doctor of technical sciences

[Abstract] The feasibility of cooling both nozzle and runner blades in a gas turbine engine by application of the heat-pipe principle is examined from the standpoint of thermogasdynamics and power transfer. The analysis is based on consideration that the temperature of the blade wall is a determining factor in the design of any cooling system and that this temperature is functionally related to the four main constraints on maximum power transfer through a heat pipe: viscous and acoustic flow in the vapor phase, capillary flow and entrainment in the liquid phase. Calculations are made for a two-stage turbojet engine, with the temperature of the blade wall determined from the approximate equation of heat balance as  $T_w = (AT_g + T_a)/(1 + A)$  ( $T_g$  - temperature of gas,  $T_a$  - temperature of ambient air,  $A = \alpha_{\text{evap}} S_{\text{evap}} / \alpha_{\text{cond}} S_{\text{cond}}$ ,  $\alpha$  - heat transfer coefficient at outside surface and  $S$  - area of outside surface in evaporation zone and in condensation zone respectively). Adequate performance of a heat pipe during variable-speed engine operation requires control of the parameter  $A$ , which is most effectively achieved by regulating the surface area  $S_{\text{cond}}$ . Model experiments were performed on individual blades forming heat pipes, with a wick made of cloth (FNS-10) or metal mesh and with liquid potassium as coolant (a heat pipe has better starting characteristics with liquid potassium than with liquid sodium). Actual flow in a real engine was simulated by rotating the blades about their horizontal axis as well as by regulating the Reynolds number and the relative cooling depth  $\theta = (T_g - T_w)/(T_g - T_a)$  in the test stand. The results indicate the feasibility of cooling engine blades below 1000 K at a gas temperature above 1400 K at any blade angle setting. Figures 3, table 1, references 3: 2 Russian, 1 Western.

## THERMALLY STRESSED STATE OF TURBINE NOZZLE VANES DURING SHUTDOWN

Kiev PROBLEMY PROCHNOSTI in Russian No 2, Feb 83 (manuscript received 17 May 81)  
pp 82-85

ANTONOVICH, A. V., TSYBENKO, A. S. and SHTEFAN, Ye. V., Kiev Polytechnical  
Institute

[Abstract] Shutdown of a gas turbine involves rates of gas temperature change 200 to 300 times greater than the rates of temperature change during startup. Vanes made of nickel alloy EI893 from the first stage of a GT-35-770-2 gas turbine at the Yakutsk Regional Electric Powerplant were studied to determine the influence of the method of shutdown on thermal stresses. The study was performed by mathematical modeling, dividing the vane up into a large number of finite elements. It was found that switching the combustion chamber to idle was approximately equivalent to reducing turbine speed from 50 to 35-37 rps from the standpoint of thermal stress on the vanes. A method is suggested for programmed gradual shutdown which can reduce thermal stresses by half. Figures 5, references 5 Russian.  
[178-6508]

## PRODUCTION OF EXTRA POWER FOR DISTRICT HEATING TURBINES

Moscow TEPLOENERGETIKA in Russian No 1, Jan 83 pp 31-35

SHAPIRO, G. A., candidate of technical sciences, Kirov Polytechnical Institute

[Abstract] The output of district heating turbines can be increased by cutting off the high-pressure regenerative heaters during peak load periods. This measure can result in lowering of the temperature of the boiler's exhaust gases, increasing the extraction of steam with a corresponding reduction in the peak boiler's load, and increasing the generation of electric power in heat consumption. An equation is given for the savings of fuel in this case. Quite considerable peak power can be produced as the result of increasing the admission of steam into the low-pressure section. With an increase in flowrate of steam into the low-pressure section from the ventilation rate to the nominal in the T-50-130, T-100-130 and PT-60-130 turbines, the internal output of these turbines increases 20 to 28 percent, depending on the operating mode and the design of the turbine plant. The rate of flow of steam into the low-pressure section can be increased above the nominal by cutting off the regenerative heaters. It is possible to increase the output of bleeder turbines by lowering the temperature of the heating-system return water. When this so-called secondary condensation method is employed, the turbine's output is increased with a considerable increase in losses of heat in the cold source, and at the same time there is an increase in the specific consumption of heat for the turbine plant,  $q$ , which depends under these conditions substantially on the specific generation of

electric power per 1 MJ of heat released and on the amount of heat removed for secondary condensation. The use of this method becomes inexpedient with  $q$  4.5 to 5. More economical methods of producing peak power have been developed at Kirov Polytechnical Institute, and they are described here. Various circuits are described which make it possible to accumulate heat. One turbine plant configuration employs the principle of cooling the heating-system return water, and the other that of producing economical peak power by increasing the flowrate of steam into the low-pressure section. The first configuration can be used both for turbines with controllable extraction of steam and for bleeder turbines. With the first configuration when it is necessary to produce peak power the heating-system return water is drained into a container and at the same time, but in a smaller amount, is pumped out of it into another container through a cooler cooled by untrated water. The cold water is fed from the second container to the heat supply system and during periods of reduced electrical loads the hot water accumulated in the first container continues to be pumped into the second, so that at the moment the peak electrical load is reached the water is completely pumped out of the first container and a sufficient amount of water is contained in the second container at the minimum possible temperature. In the second configuration, which is also based on the principle of the accumulation of heat, peak power is produced as the result of an increase in the rate of flow of steam into the condenser. The heat of this steam is fed to cooling water accumulated in a tank, and with a reduction in the electrical load the water from the tank is used as the heated raw water for chemical water treatment. Cooling of the heating-system return water is a sufficiently effective method of producing peak power. In a turbine of the T-100-130 type the increase in power per each 10 degrees of reduction in temperature of the heating-system return water can reach 4 to 4.5 MW with the flowrate of live steam equal to the maximum and 25 to 28 MW when it is less than maximum. In plants with the second configuration, in which the flowrate of steam into the condenser is increased, the increase in the turbine's power is made up of the increase in the power of the low-pressure section and of pre-extraction stages. Figures 4, references 11: 10 Russian, 1 Hungarian. [121-8831]

UDC: 621.165:621.311.25:621.039

# DESIGN STUDY OF VARIABLE MODES OF LENINGRAD METAL PLANT K-1000-60/3000 TURBINE

Moscow TEPLOENERGETIKA in Russian No 1, Jan 83 pp 26-31

LEYZEROVICH, A. Sh. and LEVCHENKO, V. L., candidates of technical sciences, and KIRILLOV, V. B., engineer, VTI [All-Union Heat Engineering Institute imeni F. E. Dzerzhinskiy] - LMZ [Leningrad Metal Plant] POT [expansion unknown]

[Abstract] Methods have been developed for mathematical modeling of the variable modes of wet-steam turbines for nuclear power plants, making it possible to arrive at switchability characteristics, to isolate so-called critical elements which restrict the speed of variable modes, and to plot assignment curves close to the theoretically optimum for these modes at the design stage. The purpose

properties of the additive material. The implementation of these processes requires high radiation power densities, since the metal must be melted: to mix it with the alloying additives in the first case, and to fuse the coating material with the base in the second.

Laser welding consists of heating and melting the sections at which the welded materials make contact. The radiation flux causes liquid metal to appear quickly, and results in the formation of a cavity. The metal in the cavity evaporates intensively, and the vapor pressure equalizes the pressure of the liquid metal flowing along the walls of the cavity. The laser beam propagates through the cavity, forming a deep, narrow seam in its path.

Laser cutting requires energy densities high enough to evaporate the material. A gas is fed to the cutting zone which is employed either to blow away the combustion products (inert gas), or to provide additional heating (an oxidizer).

In addition to their characteristic features and advantages, these methods of laser heat treatment of materials have properties in common. This includes local action and the lack of deformation in the treated articles; high speed; independence of heating and mechanical, thermal and chemical properties of the material; the capability of employing laser technology in the finishing stages of treating articles; the absence of X-radiation; the capability of fully automating the process, among others.

A laser beam has a very important quality: it is a universal means by which different technological processes can be accomplished by regulating the power density of the radiation at the point at which it acts upon the article.

The possibilities for the development of laser methods for heat treatment of materials are determined primarily by the level of laser engineering. The lasers which are needed for industrial assimilation of new technology must be reliable and easy to operate, they must have long service life and they must provide good reproducibility of radiation parameters. Lasers which satisfy these requirements are called technological lasers.

A considerable amount of research has been done in this country on developing technological lasers producing up to 10 kW. The highest powers have been achieved in CO<sub>2</sub>-lasers which employ an electrical discharge in a gas flux for excitation of the working medium. The use of a molecular gas for generating laser radiation has made it possible to increase the efficiency of the process (the quantum efficiency of carbon dioxide gas molecules is 0.41), and the use of convective cooling has increased the energy contribution level. The realization of a glow discharge in a large volume of gas makes it possible in principle to achieve the laser radiation output power levels required for thermal technology. The total efficiency of lasers is not over 0.10 because of the significant losses in the technical systems.

of this study was to develop specific recommendations for the conduct of variable modes and to plot assignment curves for starts from various thermal states on the basis of specific constraints on warmup of the basic elements of the design. Temperature stresses in the most thermally stressed, or critical, elements of steam turbines are the key factor limiting the pace of variable modes. Critical elements in zones of the formation of the greatest temperature stresses are the focus of attention here. The technique employed is distinguished by the use of special-purpose subprograms for numerical solution on a computer of non-steady-state heat conduction problems for typical design elements, i.e., unit-forged or welded rotors of wet- or superheated-steam double-flow cylinders, and elements of the flange of the high-pressure cylinder's casing at the half-spacing of stud bolt holes. The problem is solved by the method of finite differences in explicit form in a 2-dimensional formulation, taking into account the real geometrical shape of the elements considered. The thermophysical properties of the metal are assigned as the initial numerical data for the series of calculations. The procedure is also distinguished by the assignment of boundary conditions for heating surfaces by means of static, and for superheated-steam cylinders, dynamic, characteristics of the change in temperature of the heating steam with a change in parameters of the turbine's operation, i.e., the flowrate and temperature of the steam entering the cylinder. Static characteristics of the change in heat transfer coefficients are assigned for operation with superheated steam. The change in operating parameters is assigned in the form of a piecewise linearized time program with verifying calculations or is determined automatically from the instantaneous temperature state of critical elements by means of design optimization. The results are given of generalization of design optimization of loading curves for starts from various thermal states of a turbine with a high-pressure cylinder outer casing made of 20KhM-L steel. The results are given of calculations of the warmup of a low-pressure cylinder rotor in starting after two hours of downtime with controlled and uncontrolled gradual connection of the live heating steam feed system. It is shown that this type of heating is one of the most unfavorable for warming the rotor of a low-pressure cylinder. A diagram is presented for determining permissible changes in load from conditions of the temperature state of the outer casing's flange and high-pressure cylinder rotor. The results of analysis show that for the K-1000-60/3000 turbine two temperature differences--for the width of the flange and for the radius of the high-pressure cylinder rotor--should be used as leading indicators of its state in accordance with which its variable modes are controlled. A structural diagram is given of a complex of equipment for checking the warmup of the rotor and flange and for determining permissible changes in the turbine's load. This complex can be implemented with standard AKESR hardware. Figures 5, references 15 Russian.

[121-8831]

## VIBRATIONS OF BLADE RIMS OF FINAL STAGES OF STEAM TURBINE UNDER UNRATED OPERATING CONDITIONS

Moscow TEPLOENERGETIKA in Russian No 1, Jan 83 pp 22-26

KOSTYUK, A. G., doctor of technical sciences, Moscow Energy Institute

[Abstract] An increase in vibrational stresses in blades when the turbine operates with low volumetric admission of steam and with elevated pressure behind the stage has been observed in model and full-scale studies of the vibrational state of the final stages of a low-pressure cylinder used in large condensing and extraction turbines. One possible kind of vibration is self-sustained vibrations originating because with low volumetric admission of steam, the stream of steam flows into a large portion of the length of the blades with considerable negative angles of incidence. Curves expressing the relationship between axial and peripheral aerodynamic forces on the blade and the angle of inflow of the stream in the region of wide negative angles of incidence have a negative slope, which demonstrates the possibility of self-excitation of vibrations. These self-sustained vibrations are analyzed here. A model is constructed for the flow of steam in the cascade under the conditions named. Calculations are presented for aerodynamic forces in cascades and with vibrations of the rim. A method is presented for calculating self-sustained vibrations of a blade rim and an example is given of calculation of the self-sustained vibration curve for the blade rim. A sharply pronounced aerodynamic excitation maximum is observed with certain volumetric admission values, which are called "critical admission," which in turn depend on the permissible value of vibrational stresses,  $\mu$ . A diagram is presented of the permissible backpressure with various  $\mu$ . The excitability of self-sustained vibrations of the rim is maximum when the permissible backpressure has a distinctly pronounced minimum. Curves illustrate the relationship between amplitudes of stresses with self-sustained vibrations of the rim and the turbine's operating mode, characterized by the backpressure and volumetric admission. It is concluded that the permissible backpressure for final stages is determined by the design parameters of the stage and permissible vibrational stresses in the blades, and depends on the volumetric admission of steam. The rim's damping factor and excitation factor are the key design parameters influencing the excitability of self-sustained vibrations. With any fixed backpressure there exists a value of volumetric admission with which stresses reach a maximum in self-sustained vibrations. Figures 7, references 9: 8 Russian, 1 Western.

[121-8831]

## EXPERIENCE OF USING SATURATED-STEAM TURBINES FOR NUCLEAR POWER PLANTS

Moscow TEPLOENERGETIKA in Russian No 1, Jan 83 pp 12-16

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[Abstract] In the 11th and 12th five-year plan periods a considerable percentage of the growth of capacities of nuclear power plants will be due to the use of VVER-1000 reactors with a single 1000-MW turbine. This arrangement requires a high availability factor for the equipment of the secondary circuit, including for the turbine plant. The quite high reliability indicators which have been achieved for saturated-steam turbines for nuclear power plants in the USSR make it possible to plan a utilization factor of 78 percent in 1985. Data are presented illustrating the influence of turbine plants on the availability factor of nuclear power plants. Availability has been adversely affected by troubles with turbine plants, primarily with the turbogenerator set itself. It is demonstrated that the reliability of saturated-steam turbines produced in quantity by the Kharkov Turbine Plant is high and exceeds the reliability of foreign-made turbines for nuclear power plants. Erosion of stationary elements of the high-pressure cylinder has been eliminated, along with several other troubles, in KhTZ's turbines. An analysis is made of downtime for 14 K-500/65/3000 turbines during 1980. The number of failures was roughly equal for bearings, steam distribution, regulation and the oil system, but 67 percent of downtime was due to failures in bearings, 21 in steam distribution, 9 in regulation and 3 in the oil system. The reliability of saturated-steam turbines produced by KhTZ is due to a number of special design factors, including high dynamic stability of the rotor system, the extensive use of erosion-resistant materials, a sufficiently effective system for moisture removal in the flow-through section, and the employment of steam distribution through restrictors. There is potential for improving the efficiency of saturated-steam turbines and turbine plants. In the development of new turbines and modifications, stages operating on wet steam are being optimized, taking into account the use of efficient methods of moisture removal to reduce erosion and provide maximum economic efficiency. Wire connections are being eliminated in all intermediate stages because they intensify the wet phase entering subsequent stages. The dividing pressure is being increased and the reheat temperature is being lowered. The live steam flowrate in the steam feed system is being reduced at reduced loads. New turbine plants for nuclear power plants, the reconstruction and modification of equipment already in operation, optimal, operating conditions and additional research should increase the efficiency of nuclear power plant turbine units and power generating units as a whole. Figures 5, references 20: 10 Russian, 10 Western. [121-8831]



## STEAM TURBINES: SUCCESSES, UNSOLVED PROBLEMS

Moscow TEPLOENERGETIKA in Russian No 1, Jan 83 pp 6-11

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[Abstract] Modernization, reliability, economic efficiency, switchability, new designs, scientific research, goals and unsolved problems are discussed, relating to steam turbines produced in the USSR. The 10 K-800-240 turbines now in operation are the most powerful in Europe of turbines installed at fossil-fuel electric power plants. The number of standard sizes of heat-and-power-generating turbine plants has been extended. New power generating units have been installed at nuclear power plants. Single-turbine reactor-turbine combinations are being introduced at nuclear power plants. Elimination of the two-turbine system made it possible to increase the unit capacity of turbine equipment to 1000 MW. A 1500-MW power generating unit, the most powerful in the world, with two newly designed K-750-65/3000 turbines is slated for entry into service this year at the Ignalina Nuclear Power Plant. The most powerful steam turbines in the world, the K-1200-240, with a maximum output of 1380 MW, is being debugged at the Kostroma GRES. The large TK-450/500-60 heat-and-power-generating turbine for nuclear power with an electrical output of 500 MW and a heat load of 1885 kJ/h is the only turbine in the world of this sort. Plans have been approved for new turbine units which are unprecedented outside the USSR, such as for the K-300-240 turbine for an electric power plant with MHD (magnetohydrodynamic) generators. The USSR's steam turbines are in operation in 23 countries and orders from abroad are increasing. Examples of modernization are a new modification of the K-800-240-5 turbine, a second variant of the K-500-240-2 turbine and modernization of a series of heat-and-power-generating turbines. The reliability indicators of quantity-produced nuclear power plant turbines from the Kharkov Turbine Plant imeni S. M. Kirov (KhTZ) surpass those of foreign-made turbines for this purpose. Trouble with turbine equipment has been associated in part with insufficient quality control at producing plants. Reliability of turbines made for nuclear power plants and for export is higher than for turbines for other purposes. The quality of the assembly and design of some auxiliary equipment has been unsatisfactory. Unskilled operating personnel have been a source of trouble. Damage has been done to turbines because of the unsatisfactory quality of the feed water and steam. There is considerable potential for improvement of economic efficiency. With regard to switchability, the problem of converting power generating units to semi-peak units has become urgent. Computer control of turbines is seen as an indispensable condition for reliable operation in transient modes. An example of advances in research and development is the new final stages with blades 1200, 1000 and 920 mm long which are distinguished by the fact that they can operate with elevated mass flowrates of steam. Detailed gas-dynamic and vibration studies are being made of low-pressure cylinders. It is felt that a scientific and engineering conference covering all major problems relating to creating, improving and doing scientific research on steam turbines is long over-due. Current objectives and unsolved problems are itemized.

[121-8831]

UDC: 531.388

INSTABILITY OF GYROCOMPASS UNDER VARIABLE MOMENTS ACTING ON WHEEL AT RESONANCE

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 12, Dec 82 (manuscript received 17 Jul 80) pp 102-107

VOROB'YEV, V. M., Kiev

[Abstract] A gyrocompass is considered which has a sensing element on contactless suspension, a pin in a dashpot at the bottom acting as damper, and variable moments acting on the wheel. Nonlinear vibrations of such a device are analyzed on the basis of the corresponding equations of motion, assuming that the angular velocity of the wheel oscillates periodically about a constant average. Considering that the device has three natural frequencies (precession frequency  $\lambda_1$ , frequency of motion of suspension pivot  $\lambda_2$ , nutation frequency  $\lambda_3$ ),  $\lambda_1^2 \ll \lambda_2^2 \ll \lambda_3^2$ , the conditions for instability and resonance at three frequencies  $\omega = 2\lambda_i$  ( $i = 1, 2, 3$ ) are established first. The conditions for asymptotic stability at combination-frequency resonances  $\omega = \lambda_j \pm \lambda_k + \delta$  ( $j, k = 1, 2, 3$ ;  $j \neq k$ ;  $\delta$  - frequency deviation) are established subsequently, on the basis of the characteristic equation and its roots. At  $\omega = \lambda_2$ ,  $\lambda_1$  and  $\omega = \lambda_3$ ,  $\lambda_1$  the system is always asymptotically stable. At  $\omega = \lambda_3$ ,  $\lambda_1$  the system can be unstable, but can be stabilized by small adjustment of either the nutation frequency or the perturbation frequency. The results are applicable to a gyrocompass driven by a synchronous electric motor or by an induction motor with speed stabilization. Figures 4, references 12 Russian. [172-2415]

UDC: 531.383

ANALYSIS OF FORCE CHARACTERISTICS OF CRYOGENIC GYROSCOPE SUSPENSION

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian No 1, Jan-Feb 83 (manuscript received 5 Apr 82) pp 9-15

ZHURAVLEV, V. F. and RUDENKO, V. M., Moscow

[Abstract] The following problem is studied: a spherical gyroscope rotor of an ideally diamagnetic material is suspended in the magnetic field created by a closed superconducting loop. Assuming that the initial current in the loop

is known, determine the forces acting on the rotor and the rigidity of the magnetic suspension, assuming that the centers of the rotor and spherical field coincide when there is no perturbation present. An approximate method is developed for calculating the force characteristics of the suspension, yielding equations that are finite and convenient for analysis for supporting superconducting circuits of various shapes. An example is included. It is determined that the exact solution differs from the approximate solution by a very small amount. Figures 5, references 6 Russian.  
[169-6508]

UDC: 531.383

#### EQUATIONS OF MOTION OF GYROPENDULUM SYSTEMS IN RODRIGUES-HAMILTON PARAMETERS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian No 2, Mar-Apr 83 (manuscript received 11 Aug 81) pp 20-29

CHELNOKOV, Yu. N., Saratov

[Abstract] The motion of a gyropendulum system is studied, assuming that the earth is a sphere with radial density distribution, the point of suspension of the system moves over the surface of a nonrotating sphere concentric with the terrestrial sphere. The equations of disturbed motion of a three dimensional dyrohorizon-gyrocompass are obtained in Rodrigues-Hamilton parameters. References 23: 22 Russian, 1 Western.  
[187-6508]

UDC: 531.36

#### POSSIBLE USES OF INFORMATION ON CONSTANT ALTITUDE IN INERTIAL NAVIGATION SYSTEMS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian No 2, Mar-Apr 83 (manuscript received 22 May 81) pp 13-19

MATASOV, A. I., Moscow

[Abstract] A study of the equations of inertial navigation can be reduced to studying the motion of two material points moving in a field of gravitation under the influence of a single nongravitational force. The material points represent the sensing mass of the accelerometer and the point which models the device's trajectory which is being determined. The observability problem for movement of an object at a constant distance from the center of the field of gravitation is reduced to determining the set of trajectories located on a sphere of the same radius. This article studies a point of unit mass moving in a field of newtonian gravitational forces under the influence of a nongravitational force, its position defined by a single radius vector. The problem is to define the set of solutions of the equation of motion of the point with fixed external force. It is demonstrated that the set of solutions does not consist of more than 4 points. References 4 Russian.  
[187-6508]

UDC: 531.55:521.2

INFLUENCE OF DISSIPATIVE MAGNETIC MOMENT ON ROTATION OF SATELLITE RELATIVE TO CENTER OF MASS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDODO TELA in Russian No 2, Mar-Apr 83 (manuscript received 6 Jul 81) pp 3-12

SAZONOV, V. V. and SARYCHEV, V. A., Moscow

[Abstract] The eddy currents induced in the skin of a satellite by the terrestrial magnetic field cause its speed of rotation to decrease. Spin-stabilized satellites must compensate for this speed reduction. This article calculates the influence of magnetic moments on a satellite. Equations are derived which describe the evolution of Euler motion of a satellite under the influence of dissipative magnetic moments, and inequalities are derived for solving these equations. Gravitational torque and orbital regression are not considered. Figures 4, references 4 Russian.

[187-6508]

UDC: 681.121.89(088.8)

ALGORITHMS FOR HARDWARE IMPLEMENTATION OF SHIP LOCATION GRAPHIC REPRESENTATION ON NAVIGATION MAP CONSIDERING TERRESTRIAL ASPHERICITY

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian No 3, Mar 83 (manuscript received 20 Apr 81) pp 60-64

BORZENKO, A. Ye., GAVRILENKO, V. I., GAYNUTDINOVA, I. K. and MEYER, V. V.  
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[Abstract] Due to the asphericity of the earth, the length of one minute of arc on a terrestrial meridian is not equal to one minute of arc on the equator and in fact varies with latitude. Since the distance traveled onboard a ship is measured in standard nautical miles, while charts show true minutes of arc, it is necessary to consider the divergence between a standard and a true nautical mile. Equations are presented to do this. No reference is made to implementation of the algorithm embodied in the equations in hardware. References 4 Russian.

[179-6508]

ERROR OF TWO-AXIS GYROSTABILIZER WITH RANDOM BASE OSCILLATIONS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian  
No 3, Mar 83 (manuscript received 4 Nov 81) pp 56-60

LESTEV, A. M. and ROMANOVA, A. V., Leningrad Institute of Aviation Instrument  
Building

[Abstract] A dynamic system consisting of a two-axis gyroscopic stabilizer is investigated on the basis of nonlinear differential equations. The dispersion of stabilization errors and mathematical expectation of angular drift rates of the gyrostabilizer are determined. The study is based on statistical linearization of discontinuous nonlinearities including the dry friction torque. The equations derived for error can be used to select the parameters of such an instrument and determine the requirements for vibration acceleration limits for its operation. Figure 1, references 8 Russian.  
[179-6508]

LASER TECHNOLOGY: EXPERIENCE AND PROSPECTS FOR IMPLEMENTATION

Moscow PLANOVOYE KHOZYAYSTVO in Russian No 5, May 82 pp 96-102

[Article by G. Abil'sitov, Director, Scientific-Research Center for Technological Lasers, USSR Academy of Sciences]

[Text] The Basic Directions of the Economic and Social Development of the USSR for 1981-1985 and up to 1990 includes the task of "Utilizing electrochemical, plasma, laser, radiation and other high-efficiency methods for treating metals, materials and articles in order to improve their properties significantly"<sup>1</sup>. The application of laser radiation for treating materials is based on the action of the heat from a highly concentrated energy flux on the substance. The nature of this process is determined by the power density of the radiation and by the properties of the material.

One of the basic such methods of treating materials is laser hardening of their surfaces (surface heat hardening), which is done by heating followed by cooling. This method is characterized by high rates of application and release of energy, as well as the capability of localizing the process on small sections of the surface. The treatment results in the creation of a layer on the surface of the part which has a finely divided structure with increased microhardness. Under certain conditions, an amorphous layer of so-called metal glass can be created on the surface. Since relatively low radiation power densities are employed in laser hardening, and since the process usually does not involve melting, special coatings with high absorption capacity can be applied to the surface of the material.

In addition to surface heat hardening, there are two other purposeful ways of changing the surface properties of material by means of laser radiation. We are talking about surface alloying and surface facing. In alloying the additive material is melted along with the base metal and the two are mixed together in order to obtain the required surface layer composition. In facing, the process involves minimal melting of the base, with the composition and properties of the surface being fully determined by the composition and

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<sup>1</sup> "Materialy XXVI s"yezda KPSS" [Materials from 26th CPSU Congress]. Moscow, Politizdat, 1981, p 145.

Lasers which emit on vibrational-rotational transitions in the infrared region of the spectrum have high energy efficiency and are distinguished by relative hardware simplicity (especially when  $\text{CO}_2$  molecules are employed).

The most efficient devices are electric discharge CO-lasers which generate radiation with wavelengths ranging from 4.7 to 5.3  $\mu\text{m}$ . However, these have not been developed sufficiently because of technological difficulties, especially the requirement that the working medium be maintained at cryogenic temperatures.

$\text{CO}_2$  lasers are most promising from the viewpoint of practical implementation. These have been investigated experimentally, and can be equipped relatively quickly with technical means for pumping and cooling the working mixture, for maintaining the discharge and for outputting the radiation. In order to improve generation conditions, these ordinarily employ a working mixture which contains nitrogen and helium in addition to carbon dioxide gas.

The addition of nitrogen helps to improve the selective population of the upper laser level of a  $\text{CO}_2$  molecule, since the lower laser level of a molecule of nitrogen, which has a low deactivation rate, is close energetically to the upper laser level, and vibrational quanta are exchanged between the molecules of excited nitrogen and carbon dioxide gas at a high rate. Thanks to the presence of helium, the heat capacity and heat conductance of the working medium are improved, i.e., the cooling conditions during generation are better.

External-ionizer laser systems are not now in extensive use because of the technical difficulties involved in creating and operating these sources. However, the semi-self-maintained discharge itself is especially promising for the development of compact high-power lasers, since its use increases the instability development threshold both in terms of working pressure and in terms of specific volumetric power. The specific volumetric power of the energy concentration per cubic centimeter ranges from 10 W at pressures of up to 0.1 atm for a self-maintained glow discharge to approximately  $10^3$  W for pressures of up to 1 atm for a semi-self-maintained discharge with electron-beam pre-ionization. Thus, specific energy outputs of about 1  $\text{W}/\text{cm}^3$  can be achieved with laser efficiency of 10-20% in lasers with self-maintained discharge, and  $10^2$   $\text{W}/\text{cm}^3$  for lasers with semi-self-maintained discharge.

In order to generate laser radiation, the temperature of the active medium must not exceed 200-300°C. In addition, with appreciable energy inputs to the discharge and electrooptical efficiency of 0.10-0.20, the working gas temperature rises rapidly unless special cooling methods are used.

The most radical means of heat removal is to pump gas rapidly through the excitation and lasing zone and then to release the spent gas into the atmosphere, or to pass it through a heat exchanger in the case of a closed gas dynamic loop. This approach has been very effective in developing high-power technological lasers.

The main problems involved in developing powerful technological lasers have thus been the following:

- the use of a molecular gas with high quantum efficiency as the active medium;
- the use of auxiliary gases as the working mixture in order to improve conditions of inverse population of levels;
- the use of fast gas pumping in order to cool the working medium effectively;
- the investigation of glow discharge in a rapid gas flow and in a large volume of active medium;
- the use of an optical unstable resonator scheme to output the radiation at high power levels.

The successful resolution of these problems has made it possible to create a series of technological lasers with power ranging from 1 to 10 kW. These differ significantly both technically and in terms of construction, as well as in the use of different pumping methods to create high volumes of active medium. Lasers with self-maintained (longitudinal and transverse and semi-self-maintained discharge can be singled out among fast gas-discharge continuous CO<sub>2</sub> lasers (which, as we mentioned earlier, produce the highest power available today).

Lasers with longitudinal self-maintained discharge employ a discharge scheme in which the direction of the electrical field in the discharge is the same as the direction of the gas flow. Since the distance in the direction of the gas flow is usually substantial, the discharge in this scheme employs a high voltage power source, which involves certain difficulties. Even so, the main limitation on increasing the scale of the systems with this type of laser is associated with the creation of a homogeneous glow discharge in a large volume of gas and with the use of the working mixture at relatively low pressures. Therefore, the lasers in this class are now being developed with powers ranging from hundreds of watts to 1-2 kW.

The "Karat" laser, which produces 1 kW, is the best known such device in this country. This type of technological laser also includes the "Lantan" laser system developed at the Institute of Problems of Mechanics of the USSR Academy of Sciences. This system employs an original discharge scheme



with longitudinal geometry of the discharge chamber; however, the nature of the discharge (in contrast to the "Karat") is self-maintained, and the gas is pre-ionized by high voltage pulses.

Lasers with transverse self-maintained discharge are more promising from the viewpoint of creating a homogeneous excited medium in a large volume, as well as increasing the pressure of the working mixture. These are convenient for modular construction, and are in this sense more promising for the development of high power technological lasers. These lasers have a broader operating range -- from hundreds of watts to 10 kW.

The best known systems in this class abroad are the 1.2 kW (model 971), 2.5 kW (model 973) and 5 kW (model 975) lasers produced by the U.S. Spectra-Physics Company. The model 975 is comprised of two model 973 lasers. However, because of a number of peculiarities the treatments create high-power technological lasers.

Developments in this class in this country include the "Lok-2" system (Institute of Theoretical and Applied Mechanics, Siberian Department, USSR Academy of Sciences), the LT-1 (Institute of Atomic Energy imeni Kurchatov) and the 23 Ye (Scientific Research Center for Technological Lasers, USSR Academy of Sciences). The great deal of experimental experience which has been gained with the latter two systems has served as the basis for developing a standardized series of technological lasers employing a transverse self-maintained discharge, based on a 5 kW module. The Scientific-Research Center for Technological Lasers of the USSR Academy of Sciences, in conjunction with the All-Union Scientific-Research and Planning-Design Institute of Electric Welding Equipment of the Ministry of the Electrical Equipment Industry, is developing such a module (the TL5-system); the first models will be built during the present Five-Year Plan.

As was noted earlier, when high power levels are employed it is best to use semi-self-maintained discharge electron-beam lasers. Because of the superior stability of the semi-self-maintained discharge and the possibility of utilizing more dense active media (up to 1 atm and higher), lasers of this type are significantly more compact. Lasers in this class include the 10 kW (HPL-10) and 15 kW (HEPL-15) lasers produced by the U.S. Avco Company.

The Soviet Union has also gained a significant amount of experience in research and development on such lasers (these are called electro-ionization lasers in this country). The main research centers are the Physics Institute imeni Lebedev of the USSR Academy of Sciences (FIAN) and the scientific-research institute of Nuclear Physics of the Moscow State University imeni Lomonosov. In particular, FIAN, in conjunction with a number of branch institutes, has developed a 10 kW technological electro-ionization laser (the "Iset" system).

Of course, the above analysis of fast continuous gas-discharge lasers is somewhat arbitrary. Nonetheless, it reflects the existing trends in the planning and organization of powerful technological laser development.

Other types of electrical discharge pumping are also being studied for use in fast continuous gas discharge lasers. These include the so-called combined discharge (semi-self-maintained discharge with ionization by periodic high voltage pulses), and alternating-current discharge at  $10^4$ - $10^5$  Hz. In terms of characteristics (working pressure, specific energy output) these types of discharges are intermediate between the self-maintained d.c. discharge and the semi-self-maintained discharge with electron beam; in terms of technical implementation they are comparable or close to the former.

The possibility of using inexpensive non-helium mixtures, or of solving the problem of regenerating working gas, is of major importance for the extensive utilization of technological lasers in industry. Both halves are valid, and experimentation is now underway. In particular, a 23Ye system has been used to investigate the laser generation mode with a mixture not containing helium, and the results have been promising.

Besides fast continuous systems, tubular constructions with diffusion cooling have begun to be used actively in recent years for creating powerful technological lasers. As is well known, the first gas lasers were gas tubes (or cuvettes) with gas pumping by a longitudinal self-maintained discharge. Increasing the power of such lasers requires lengthening the active zone, which can reach several tens of meters for powers of 1 kW. For example, the "Kardamon" system produced in the Soviet Union consists of four parallel tubes 6 cm in diameter and 6 m long. This system produces steady-state lasing at the 0.8-1.0 kW level, with specific radiation output of the order of 40 W/lin.m.

In the best lasers with this construction the specific power per unit length of discharge tube does not exceed 75 W/lin.m. Furthermore, these lasers have a limit in terms of total radiated power (not exceeding 3 kW) because their maximum length is limited by diffraction phenomena. The escape from this situation, and consequently the possibility of increasing the power of diffusion-cooled lasers and decreasing their size, were found by switching over to multi-channel construction.

This represents a dense packaging of parallel discharge tubes combined by two common mirrors, one of which is semi-transparent (to output the radiation). The gas in the tubes is cooled by diffusion on the walls of the tubes, which are flushed with a coolant, and poisoning of the laser mixture is prevented by slow pumping of the gas. The laser assembly can contain any number of tubes, with the size being limited by the dimensions of the resonator mirrors and by removal of heat from the inner tubes.

The construction of a multi-channel tube-type laser solves the problem of the dimensions of technological lasers with diffusion cooling (in addition to which these systems are technically very simple); however, the radiation divergence in such a laser is substantial, and cannot surpass the divergence of the radiation taken from one discharge tube. As a result, the radiation power density at the focal point is less than  $10^6$  W/cm<sup>2</sup>; consequently, the use of this radiation is limited in metal treatment technology.

The multi-channel scheme was first tested on the "Iglan-3" system (Institute of Problems of Mechanics of the USSR Academy of Sciences). The "Iglan-3" laser consists of 39 parallel tubes 1 cm in diameter and 4 m long arranged between two flat copper (opaque) and KSi single-crystal (semi-transparent) mirrors. A system of electrodes in each tube produces a d.c. discharge with a specific volumetric energy contribution of about 2 W/cm<sup>3</sup>. The laser output power is 3 kW, with specific power output of about 20 W/lin.m.

One of the serious technological difficulties in developing multi-channel technological lasers is the requirement for placing a large number of electronic elements in a small-diameter tube and ensuring dielectric strength among a large number of conductors with densely packaged tubes. These problems are almost completely eliminated by using a capacitive (electrodeless) a.c. discharge. Pumping by a 10 kHz a.c. discharge has been accomplished on the MKTL-1 laser system at the Institute of Atomic Energy imeni Kurchatov, which has produced output power of more than 1 kW. The laser assembly consisted of 61 glass tubes 5 mm in diameter and 1 m long. The outside diameter of the assembly was about 75 mm.

The use of alternating current in multi-channel technological diffusion-cooled lasers simplifies the construction and reduces the dimensions of the lasers significantly. The elimination of a system of active ballast resistances, replacing them with capacitive loads which do not cause active losses of the power from the laser power source, is extremely important. The possibilities of developing powerful technological lasers of this type seem promising; however, thorough experimental verification is needed. The Institute of Atomic Energy imeni Kurchatov and the Scientific-Research Center for Technological Lasers are now working on experimental design development of the MKTL-2 laser, which is supposed to output 2 kW. It is possible that lasers of this type producing 5 and 10 kW will be developed in the future.

There are about 50 laser systems in this country with output power exceeding 1 kW. Practically all of these are experimental, and require some degree of refinement in order to allow them to be used under actual production conditions. Even so, many of these are already being used extensively for technological experiments and for studying various methods of laser treatment of materials; in a number of cases, they are being used to try out technological cutting, welding and heat strengthening of specific

machine building articles. This is being facilitated to a great extent by the active work of more than 20 industrial enterprises and branch technological institutes, which hold nearly half of the country's pool of high powered laser systems. These essentially provide a far-flung technological and experimental base for the development of laser material treatment technology, where the most effective areas of application are being defined.

Let us now consider the most important and promising directions of this research. It must first be noted that laser technology must not be viewed as some universal means for treating materials which must replace practically all existing technological metal treatment approaches. Obviously, the technological processes to be investigated first are those in which the decisive role is played by the properties inherent in laser radiation: high precision and local action, transportation of the laser beam over distances and remote control of the beam, absence of mechanical interaction with the part, and capability of being operated in the open atmosphere.

In the final analysis, the use of laser technology is justified where it can result in the creation of a fundamentally new treatment method, or where it can provide a substantial gain in labor productivity and product quality. Also important is the possibility of automating technological processes utilizing laser radiation. In this sense, besides investigating and working out the processes, the problem of creating automated laser technological systems employing industrial robots and manipulators must be resolved.

✓ The first steps of laser technology in treating metals involve primarily the use of laser beams for welding and surface heat treatment. At first, surface heat treatment to increase the wear resistance of the cutting edges of tools and of the rubbing surfaces of motor parts seemed to be exceptionally promising and suggested extensive utilization in various branches of machine building. However, development of this technology requires the satisfaction of rigid requirements for laser radiation performance which most domestic developments are presently unable to do. Therefore, surface laser heat treatment has been accomplished only for some types of stamping tools (at the "ZIL" production association in Moscow) and for certain motor vehicle parts (specifically, at the AZLK [Moscow Order of Labor Red Banner Motor Vehicle Plant imeni Lenin Komsomol]).

Practically every instance of surface heat hardening has employed the well-developed "Kvant", "Kardamon" and "Katun'" series laser systems. The continued development and utilization of this exceptionally effective technology requires the creation of new more powerful and sophisticated technological lasers. For example, the "ZIL" production association has plans to set up an industrial line in 1983 for surface hardening of the cylinder head of the ZIL-130 truck using an MKTL-2 multi-channel

technological laser. The successful accomplishment of this task will double or triple the service life of the cylinder head (by using a powerful laser beam to create a finely divided structure in the exhaust gas release zone, thus eliminating the threat of metal erosion), and to save a significant amount of metal. "Kometa" technological laser systems based on the "Karat" radiator will also be used extensively for analogous purposes in machine building.

For the above reasons, laser welding has now been developed to the greatest extent. This has been facilitated to a significant degree by the wide use of the LT-1 technological laser. Some enterprises and technological organizations are now using this system. The role of the system (and its numerous modifications) in the development of laser technology for materials processing is an important one.

In spite of some deficiencies, the LT-1 laser is being used successfully for welding various machine building articles. In 1981 the Moscow Cardan Shaft Plant (of the "ZIL" production association) developed an experimental industrial section for cardan shaft welding based on an LT-1 laser. Laser welding is a high-precision process; therefore, it has made it possible to almost completely eliminate the deformation of cardan shafts which usually occurs during arc welding. The lack of deformation in welding important parts for motor vehicles or other machinery makes it possible to double or triple the service life of these articles. There are plans to implement laser welding of "Zhiguli" automobile cardan shafts at the Volga Automobile Plant in the near future. This is being worked out by the Institute of Electric Welding imeni Ye. O. Paton in conjunction with other organizations.

Major gains are also achieved when laser welding is used for high-strength steel. During arc welding, an overheated zone forms at some distance from the melt line which has enlarged austenite grains and carbide lattice, which reduces the corrosion and fatigue strength of the welded joints. When lasers are used to weld this type of steel, the size of the austenite grain is from 5 to 7 times smaller, and there is practically no carbide lattice.

However, the high-precision properties of laser welding are most manifest in welding framework articles and for "pipe-to-tube sheet" type joints. The use of non-deforming laser welding in finishing operations for joining parts which have been worked "to dimension" makes it possible to eliminate post-assembly cleaning of assemblies, and reduces significantly the amount of labor involved in fabricating articles. There are examples of the highly efficient use of laser technology in welding framework articles in industry in this country. As concerns its use for making "pipe-to-tube-sheet" joints, there are plans to do this for heat-exchange equipment in chemical machine building. It is important here to achieve a high degree of "dagger" melting and to ensure that the beam "tracks" the joint well. Total

automation of the process and constant monitoring of the condition of the welded joint are necessary elements in solving this problem.

Interest has increased in applying coatings with pre-assigned properties in recent years in connection with achievements in powder metallurgy. In this case a powerful laser beam is an irreplaceable means for reliably melting the powder together with the base material. The laser method for applying coatings of powder materials can also be used successfully to repair worn parts for various machines and mechanisms.

Laser (or gas-laser) cutting and dimension working of materials are also quite common. Since plasma and gas-plasma methods are widely used for cutting medium and large thicknesses, laser cutting is used for cutting thin steels, and for dielectric and composition materials. As a rule, laser cutting is a highly productive process which provides a good quality cut; there is no warping of the material when cutting thin sheets. The use of laser radiation may also be effective for tunneling in and destroying hard rock. However, the practical use of this method requires lasers more powerful than those now available.

Another area of laser application should also be mentioned, for which the capability of using the laser beam on a part being worked from a distance is essential. This is very important, for example, in nuclear power engineering, where feeding the laser energy into the reactor core makes possible the required process without taking additional safety measures and without halting production. This, of course, is a very difficult area for laser technology implementation; however, there is no doubt that its solution can produce a huge effect, even for isolated specific tasks.

It is now still difficult to determine the economic effectiveness of introducing laser technology for working materials into different branches of the economy. However, some estimates can be made of the effect to be gained by using laser technology, for example, in the motor vehicle industry.

The laser welding of cardan shafts mentioned above can provide sector-wide savings totaling about 1 million rubles per year, mainly through improving the quality of welded joints, increasing the service life of the universal joint center cross and the joint itself, and increasing labor productivity.

Major savings can be provided by using lasers for heat strengthening of the cylinder heads of the ZIL-130 truck. This process makes it possible to increase the resistance of the cylinder head to detonation destruction from 190 to 500 hours of operation. This makes it possible to reduce the standard for replacement cylinder heads carried in stock from 20 to 16 per

100 trucks per year (as many as 43% of all cylinder heads in operation in motor pools throughout the country are now damaged and malfunction annually.)

The preliminary savings from using laser strengthening of the cylinder head of the ZIL-130 motor total 1.8 million rubles per year. Substantial savings (about 0.8 million rubles per year) can also be provided by laser heat treatment of the inside surface of the cylinder sleeves of the ZIL-130 and the ZIL-375 motor. The implementation of this process will make it possible to increase the operating strength of the sleeve in the zone of maximum wear, to conserve expensive Niresist (alloy) material, to simplify the manufacturing technology and conditionally to free 50 workers.

Overall for the entire motor vehicle industry, the implementation of laser technology for cutting, welding and heat strengthening of motor vehicle and tool parts can provide savings of 10 million rubles during the 11th Five-Year Plan, can conserve about 5000 tons of rolled metal and can conditionally free at least 500 workers.

We do not now have a sufficient experimental base in order to accelerate research on introducing laser technology into the national economy. We are also lacking the needed production capacities to facilitate the creation of experimental systems or, furthermore, equipment for integrated development of the technological process. All of this is retarding work progress; however, this country has recently begun to build up a defined system for developing and introducing laser technology into the national economy. A unified scientific-methodical and coordinating center has been created: the Interdepartmental Scientific-Technical Council on Problems of Laser Technology of the State Committee for Science and Technology and the Presidium of the USSR Academy of Sciences. This council has a major role: it essentially determines the policy for laser technology development throughout the country. The council has united all of the specialists involved in this area of science and technology and has channeled their work in the same direction. One result of the activity of the council and its sections was the development of an integrated goal-oriented program which has been authorized by Gosplan SSSR, the State Committee for Science and Technology and the USSR Academy of Sciences as one of the most important scientific-technical programs of the 11th Five-Year Plan. The integrated goal-oriented program has defined specific tasks for the development and introduction of laser technology for 1981-1985, and has defined the obligations of the large number of organizations participating in the program.

The industrial ministries will participate actively in the development of laser technology. Lead ministries have been identified which are responsible for the development of laser technology and auxiliary equipment.



A major role in developing various technological processes involved in laser treatment of materials belongs to the base laboratories and experimental sections which have been set up at many major enterprises and at many leading technological centers. The development and growth of these laboratories and sections are essentially determined today only by the possibility of fabricating a laser system. Therefore, the utilization of new laser systems and fabrication of systems which have been proved experimentally is the next important element of the integrated goal-oriented program. By the end of the 11th Five-Year Plan the number of powerful technological lasers will have doubled, totaling at least 100 units. This will make it possible to create new technological laboratories and sections and, what is most important, to approach the planned utilization of laser technology at industrial enterprises.

However, the introduction of laser technology into production (because of the complexity of the technological process and of laser equipment, and the need for creating automated systems) may be retarded significantly if the process is not implemented experimentally and if the equipment is not tested. It is well known that the assimilation of new technology -- from developing scientific ideas to the creation of the process and introduction of new technology at the plant -- is often interrupted, not reaching the objective, or is dragged out for many years.

Of course, there is not and cannot be any universal recipe for solving this, perhaps most complex, problem of scientific and technological progress. However, the general direction of the approach to solving it is obvious: the "idea-production" chain must be consolidated. As a rule, institutes are limited to developing (or, in the best case, demonstrating) new ideas and technical solutions, but this is not enough to utilize an idea in production. The stage of experimental implementation of a technological process with its problems of developing and fabricating experimental models of new equipment thus "falls between two stools", generating hot discussions between the representatives of science and production, who often are transformed from like-thinking individuals to implacable opponents. In order to speed up the introduction of new scientific ideas into production, a special experimental-production base is needed; then the "idea-production" chain will gain the link which is now lacking -- "experimental implementation".

Experience in implementing laser technology confirms this conclusion. It is for this reason that the USSR Academy of Sciences is setting up a specialized scientific research center which incorporates a design bureau and experimental production along with scientific laboratories. This will make it possible to facilitate the experimental implementation of various technological processes employing lasers, and to introduce laser technology in an integrated fashion at the orders of enterprises. The experience thus gained in the integrated utilization of laser technology in industry will make it possible to set up series production of laser technological systems for extensive use in the national economy at minimum cost.

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UDC: 533.6.011

# INFLUENCE OF NOZZLE PROFILE ON GAS DYNAMIC LASER CHARACTERISTICS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 6, Nov-Dec 82 (manuscript received 3 Apr 81) pp 163-167

KIREYEV, V. I., MININ, S. N. and PIRUMOV, U. G.

[Abstract] A numerical parametric study is presented of the influence of geometric and gas dynamic parameters on the nature of nonequilibrium processes occurring in a two-dimensional flow of a mixture of gases in the subsonic and supersonic areas of flat and axisymmetrical nozzles. The subsonic and transsonic areas of the nozzle are studied by solution of the inverse problem considering relaxation processes. The profile in the expanding portion of the nozzle is calculated by the classical method of characteristics, with the inverse problem solved based on assigned flow parameters in the exit cross section in the isentropic approximation, then oscillating-nonequilibrium flow is calculated in the supersonic area based on the distribution of pressure along stream tubes. Of the two classes of CO<sub>2</sub> gas dynamic laser nozzles studied, nozzles based on uniform characteristics are more effective from the standpoint of reducing losses of oscillating energy in the resonator area. When there is a sharp edge at the exit of a nozzle cascade using nozzles of this type, a high degree of uniformity of all gas dynamic parameters is achieved. Figures 5, references 15: 14 Russian, 1 Western.  
[168-6508]

## ELLIPSOMETRIC STUDY OF MECHANICALLY POLISHED SPECIMENS OF CERTAIN OPTICAL GLASSES

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 3 Feb 82) pp 60-62

MASLOV, V. P. and ODARICH, V. A.

[Abstract] Results are presented from ellipsometric studies of mechanically polished surfaces of optical glass specimens type LK5, K8, TF10 and quartz glass type KB. Some new specifics of ellipsometric curves are found. The specimens were polished by conventional techniques. The results of experiments showed that the variations of  $\cos \Delta$  and  $\tan \rho$  as functions of the angle of incidence are similar to those observed in studies of other optical materials. Polishing of chemically unstable glass leads to uncontrolled changes in properties in a thin surface layer as a result of chemical interaction with the polishing suspension. The ellipticity of radiation reflected from the surface of such glasses therefore does not correlate with the polishing depth, but rather depends on various factors which appear as random factors under these experimental conditions. Under identical conditions of working the depth of the disrupted layer in LK5 and K8 glass is approximately equal to the diameter of the abrasive, while in KB glass it is half as deep. Figure 1, references 5 Russian.  
[185-6508]

## INTERFERENCE OPTICAL FILTER BASED ON LIQUID CRYSTAL

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 20 May 82) pp 49-51

MAKSIMOV, V. I. and GOPKO, A. N.

[Abstract] This work determines the requirements for thickness of a liquid crystal layer and its permissible nonuniformity in an interference optical filter. The filter consists of crossed or parallel polarizer and analyzer with a liquid crystal cell between them which can change the difference in indices of refraction of the ordinary and extraordinary rays under the influence of an electrical voltage. Equations are presented which can be used to define the requirements for layer thickness and its uniformity. The layer thickness depends on the type of liquid crystal and lies between 1 and 40  $\mu\text{m}$  for liquid crystals with  $\Delta n = 0.4$  to 0.05. Nonuniformity depends on thickness and for 1 to 40  $\mu\text{m}$  thickness falls within limits of 0.01 to 0.08  $\mu\text{m}$ . When liquid crystals with low values of  $\Delta n$  are used, the requirements for layer thickness uniformity are less rigid. Figures 2, references 9: 7 Russian, 2 Western.  
[185-6508]

## CHANGE IN POLARIZATION STATUS OF DIVERGING LIGHT BEAM IN REFLECTING PRISM

Leningrad OPTIKO-MEKHANICHESKIY PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 29 Mar 82) pp 47-49

MAKSIMOVA, N. F.

[Abstract] Results are presented from calculation of the basic polarization parameters of radiation passing through an AR-90° prism with an aluminum coated reflecting face. Ellipticity, slope of major axis of polarization ellipse, phase difference between mutually perpendicular components and energy coefficients of transmission are calculated. It is found that the polarization parameters change significantly as a function of the incident angle of radiation at the prism, material of the prism and type of coating. The material of the reflecting surface of the prism significantly influences output polarization parameters. For an aluminum coated prism the output characteristics of polarized radiation are not symmetrical about 0°. The change in output characteristics is not over 1% for incident angles of not over  $\pm 10^\circ$ . The maximum transmission factor is not over 0.86. Figures 3, references 5: 4 Russian, 1 Western.  
[185-6508]

## USE OF LENS COMPENSATOR TO TEST WIDE-APERTURE HYPERBOLIC SURFACE

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 17 Feb 82) pp 42-44

BUBIS, I. Ya., PURYAYEV, D. T., and ROBACHEVSKAYA, V. I.

[Abstract] Testing of lenses with a lens compensator does not have the shortcomings of the use of an autocollimation system with an additional spherical mirror. However, as the aperture of the mirror increases, the requirements for accurate centering and determination of distance between optical elements in the compensator as well as its position in the test circuit increase greatly. This article describes experimental testing of a test circuit using a lens compensator for testing of a hyperbolic reflector surface 1080 mm in diameter with an aperture of 0.4 and asphericity of approximately  $320 \lambda$ . Testing was performed using a 632.8 nm laser beam. The compensator itself consists of three air-spaced elements. Analysis of the influence of changes in the parameters of the compensator on residual aberrations of the entire system showed that the greatest requirements must be placed on the air gaps between lenses two and three (closest to reflector being tested), centering of the compensator lenses and centering of the compensator relative to the reflector being tested. Precise centering and spacing of the compensator was achieved by the design of the compensator and its

assembly and adjustment, monitoring of the quality of adjustment of the compensator in a special optical circuit and the method of adjusting the system and the hyperbolic surface being tested. Figures 3, references 3 Russian.  
[185-6508]

UDC: 666.1.035.2

#### PROGRESSIVE METHOD OF PRODUCING LENS TYPE OPTICAL PART BLANKS

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 7 Apr 82) pp 39-41

SHTANDEL', S. K., ARKHIPOV, O. N. and BUZHINSKIY, I. M.

[Abstract] Reducing the machining allowance of lens blanks by reducing the thickness of the defective layer around the outside of the blanks requires new manufacturing methods for the blanks. Progressive methods include production of blanks by cutting of cylindrical glass rods into tablets. Cylindrical glass rods can be produced by diamond drilling of large glass blocks or by continuous extrusion and drawing of a glass cylinder from a large billet heated to the softening point. A method has now been developed for production of optical part blanks up to 50 g in mass from molten glass with measured portion injection feeding of the press. A liquid fed press is diagrammed, showing the blades which cut off the flow of fluid when the press blank is filled, the continuous molten glass feeding apparatus and the die which forms the lens blank by pressing a molten glass portion. Production of blanks from molten glass significantly reduces the consumption of optical glass by decreasing glass waste. Figures 4, references 3 Russian.  
[185-6508]

UDC: 681.7.066.3

#### SERIES MANUFACTURE OF CONVEX ASPHERICAL CONDENSER LENSES

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 6 May 82) pp 35-38

ROSHAK, A. F., LYSYANNYY, Yu. K., KHOKHLENKOV, L. N., ZHIZHENKO, G. A., NOL'D, I. I., KIRILINSKIY, S. S. and ANTANOVICH, I. M.

[Abstract] This work is dedicated to development and creation of equipment, a technological process and a testing method for series production of convex elliptical balanced condensers. The "Ellipsoid-100" experimental tool is intended for deep and precision diamond grinding of aspherical convex surfaces without bend points by trajectory copying. A standard cup-shaped tool made of M1 metal binder with diamond powder is used. Diagrams of the tool and the grinding head are presented. The tool is controlled by an Elektronika-D3-28 microcomputer. Ten minutes of machine time are required to grind one

condenser lens, which spins at 600 rpm beneath the moving cup-shaped grinding tool. The equipment and technological process are suitable for the manufacture of other types of convex aspherical condenser optical surfaces as well. Figures 4, references 7: 3 Russian, 4 Western.  
[185-6508]

UDC: 621.9.048

#### ELECTRON BEAM INSTALLATION FOR WELDING THINWALL BODIES

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 30 Mar 82) pp 33-34

VOL'FSON, L. Yu., VASICHEV, B. N., BDULENKO, A. P., ZEKHTSER, R. I.,  
YEPIFANOV, V. N., KABANOV, A. N., LUTCHENKO, G. Ye., PLISKOVSKIY, V. Ya.,  
ROZENFEL'D, L. B. and ROSLYAKOV, Yu. V.

[Abstract] An electron beam vacuum installation developed by the authors and intended for welding of thinwall metal bodies of electric vacuum instruments in an oil-free vacuum is described. The installation includes an electron gun, adjustment, focusing and deflection system, operating chamber, supporting stand and power supply. The triode type electron gun forms the electron beam. Electromagnetic electronic prisms adjust and deflect the beam. The operating chamber of the installation is a horizontal cylinder 642 mm in length, inside diameter 360 mm. The evacuation system produces an oil free vacuum of about  $1 \cdot 10^{-4}$  Pa by means of magnetic discharge pumps. A photograph and summary of technical characteristics are presented.  
[185-6508]

UDC: 62.52.001:535.885

#### CONTROL OF PROCESS OF ADJUSTMENT OF OPTICAL LINES OF MULTICHANNEL LASER INSTALLATIONS

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 7 Jul 82) pp 15-18

STAKH, V. M. and GAVRILOVA, G. S.

[Abstract] Multichannel laser systems for production of high temperature plasmas cannot be created without the use of automatic control devices. This work demonstrates that the task of automatic maintenance of an optical channel in the adjusted state may require a combination of linear and angular adjustments for the entire optical system, achieved by solving a system of linear algebraic equations. A system structure intended to implement the algorithm suggested is diagrammed and discussed. The task of orienting the optical elements of a multichannel laser installation in both linear and angular coordinates can be solved by local control loops based on closed tracking

systems controlled by a common control circuit which seeks out mismatched coordinates by means of a linear model and subsequent connection of the local control loops at mismatch points. A reduction of adjustment time by a factor of 10 to 15 in comparison to manual control of the device can be achieved. References 2 Russian.

UDC: 531.717.8

#### INFLUENCE OF METAL SURFACE OPTICAL PROPERTY HETEROGENEITY ON REFLECTOMETER INDICATIONS

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 31 Mar 82 ) pp 8-10

ASHKEROV, Yu. V., GOLUBEV, S. G. and LOKHOV, Yu. N.

[Abstract] A method is discussed for determining  $\sigma$  of optical surfaces. Expressions are presented for the relative error in the value of  $\sigma$  resulting from random deviations in coefficient of reflection. Deviations of coefficient of reflection from its value for an ideally pure metal resulting from charging are studied. It is found that in reflectometric measurements the effect of contamination of the metal surface with a fine abrasive can lead to significant errors in determination of  $\sigma$ . Estimates indicate that reflectometry can be used to study supersmooth surfaces since it allows the influence of surface optical property heterogeneities to be decreased. A method including comparison with a standard surface is applicable only for rather hard metals preventing the impression of foreign particles. References 5: 4 Russian, 1 Western.  
[185-6508]

UDC: 681.42:535.8

#### MATERIAL PARAMETERS DETERMINING SURFACE ACCURACY OF LARGE ASTRONOMICAL MIRRORS

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 29 Dec 81) pp 4-6

AMUR, G. I.

[Abstract] Factors which influence the accuracy of surface generation in large astronomical mirrors are discussed. Deformation of the wave front on the mirror's surface is said to be determined by the difference in birefringence, the absolute values of maximum and minimum refraction and the proper selection of optimal loading on the instrument. The rest time which the mirror needs before each test session of the surface after polishing is

determined by the temperature deformation. An equation is presented for calculation of the minimum rest time. The influence of an individual ripple on surface deformation of an astronomical mirror can be eliminated by placing it horizontally, causing the stress component of the ripple to be equal to 0. Figures 2, references 4 Russian.  
[185-6508]

UDC: 527.62

#### SELECTION OF EQUATORIAL STAR COORDINATES BASED ON COMPUTER PRINTOUTS TO CALCULATE AZIMUTHS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian No 3, Mar 83 (manuscript received 24 Feb 81) pp 65-68

SERGEYEV, M. A., YUSHCHENKO, V. I., LEVANENKO, V. A. and RYSAKOV, A. A., Leningrad Institute of Precision Mechanics and Optics

[Abstract] An astronavigation system has been developed by the authors' institute in which angular coordinates of a moving object are calculated from quantities representing the position of the horizontal geographical and object-attached systems of coordinates relative to stellar coordinates. The system can be used under weightless conditions, since no pendulum correctors or accelerometers are used. The position of the horizontal geographic system of coordinates relative to the stellar system is described by the computed altitudes and azimuths of two stars. Equations are presented for computation of the equatorial coordinates of stars. Processing can be done by computer using a standard routine to construct the equatorial coordinates of the stars and determine the maximum possible mean square error of the computed azimuths. It is found that when stars in the northern celestial hemisphere are used the error in determining geographic coordinates has significantly less influence on the mean square error of the computed azimuth. Figure 1, references 4 Russian.  
[179-6508]

UDC: 539.1

#### PRODUCTION OF PURE BEAMS OF NUCLEI IN THE JINR SYNCHROPHASOTRON

Moscow ATOMNAYA ENERGIYA in Russian Vol 54, No 3, Mar 83 (manuscript received 16 Apr 82) pp 202-203

BEZNOGIKH, Yu. D., VADEYEV, V. P., VOYEVODIN, M. A., VOLKOV, V. I., DONETS, Ye. D., DUDNIKOV, V. G., ZINOV'YEV, L. P., MONCHINSKIY, V. A., PIKIN, A. I., SEMENYUSHKIN, I. N., SLEPNEV, V. M., KHOROZOV, S. A. and TSARENKOV, A. P.

[Abstract] The JINR synchrophasotron at Dubna is regularly used to generate beams of nuclei of elements heavier than helium, particularly carbon. The

"Krion-2" cryogenic electron-beam ionizer can produce even heavier nuclei,  $\text{Ar}^{18+}$  and helium-like  $\text{Xe}^{52+}$  ions. The limitation of mass of beams accelerated to relativistic energies is primarily one of the losses in the process of synchrotron acceleration due to electron capture by nuclei in the beam upon collision with atoms of residual gas in the synchrophasotron chamber. A photoemulsion track of 73 GeV  $^{22}\text{Me}$  nuclei is presented. The process of determining the relationship of accelerating voltage to synchrophasotron magnetic field for acceleration of  $^{22}\text{Me}$  is described. Figures 4, references 9 Russian.



UDC: 532.5:532.135

STEADY ROTATION OF ARBITRARY AXISYMMETRIC BODY IN BOUNDLESS VISCOPLASTIC MEDIUM

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 2, Feb 83 (manuscript received 23 Sep 80) pp 68-72

KOLOBOVSKIY, Yu. Ya., Yaroslavl Polytechnic Institute

[Abstract] A convex axisymmetric solid generated by rotation of any sufficiently smooth  $y = y(x)$  is considered rotating slowly and steadily about the  $Ox$  axis in a boundless viscoplastic medium. The rotation is slow so that body and inertia forces can be disregarded. Steady rotation results in formation of a shear flow zone with an inner boundary at the body surface. Its outer boundary is determined here from the equation of motion containing two Lamé coefficients in an orthogonal system of curvilinear coordinates, assuming the width of this zone is smaller than the radius of the body cross section. This equation is solved in accordance with boundary-layer theory. Further calculations yield the shearing stress at the body surface and the torque necessary for accelerating the body from almost rest to its final speed, with the Il'yushin parameter made to approach infinity. The minimum torque is required by a cylinder ( $dy/dx = 0$ ). The two simplest shapes with  $dy/dx \neq 0$  for which the starting torque can be easily evaluated are a cone and a sphere. References 6 Russian. [173-2415]

UDC: 624.074.4:539.384+532.25

QUASI-STATIC LOSS OF STABILITY BY ROTATING CYLINDRICAL SHELL WITH FLUID

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 2, Feb 83 (manuscript received 20 Nov 80) pp 58-63

BADRUKHIN, Yu. I., KUZNETSOV, V. V., POPOV, Yu. S. and SKACHKOV, Yu. V., Novosibirsk

[Abstract] The stability of a circular cylindrical shell under internal pressure and rotating about its axis together, as one body, with a fluid partially filling it is analyzed for the possibility of circumferential

flexural equilibrium modes. The cylinder is assumed to be infinitely long, but the problem can be reduced to that for an inextensible ring of unit width. The system of two second-order equations of stability taking into account changes in magnitude and direction of the load forces in the deformed state is reduced to one sixth-order equation in deflections and a solution to the latter is sought which satisfies the condition of periodicity. The critical velocity of the shell corresponds to the wave number  $k=2$ , the wave number  $k=1$  corresponding to rotation of the fluid as a rigid body. The behavior of the ring after loss of stability is analyzed by the energy method according to the virtual work principle. For a cylindrical shell of finite length on hinge supports, the expression for the critical angular velocity based on the semizero-moment theory indicates when flexural equilibrium modes are possible depending, among other things, on pressure. Figures 3, references 4 Russian.  
[173-2415]

UDC: 533.6.013.42:518.12

#### DYNAMICS OF SOFT BRAKING SYSTEMS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 1, Jan-Feb 83 (manuscript received 28 Apr 82) pp 47-54

BELOTSEKOVSKIY, S. M., DNEPROV, I. V., PONOMAREV, A. T. and RYSEV, O. V.,  
Moscow

[Abstract] A study is made of the interaction of a system consisting of a load plus a parachute with the air stream moving past the parachute by means of an approach based on synthesis of numerical methods of nonlinear aerodynamics and elasticity theory, including solution of control equations from nonsteady, nonlinear aerodynamics, generalized nonlinear elasticity equations and equations for the dynamics of movement of the parachute plus its load. The problem of determining the instantaneous shape of the parachute and its stress-strain state is reduced to integration of a system of nonlinear partial differential equations. The number of equation systems which must be integrated depends on the shape of the parachute and the number of lines connecting the edge of the parachute to the load. Two examples are included. Figures 5, references 7: 4 Russian, 3 Western.  
[169-6508]

UDC: 532.5+62-50

#### KINEMATIC CONTROL OF MOVEMENT OF VESSEL WITH IDEAL HEAVY FLUID

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 1, Jan-Feb 83 (manuscript received 1 Mar 82) pp 39-46

AKULENKO, L. D., Moscow

[Abstract] A study is made of the problem of controlling the motion of a rectangular absolutely rigid vessel containing an ideal heavy fluid. The vessel can move only horizontally. The movement of the system is described using a linear model of infinitesimal waves. Simple control rules are obtained to allow the movement of the vessel to be controlled as desired without oscillation of the liquid. Figures 3, references 12 Russian.  
[169-6508]

UDC: 532.58.031

#### MOVEMENT OF CIRCULAR CYLINDER IN RECTANGULAR CHANNEL

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 1, Jan-Feb 83 (manuscript received 22 Dec 80) pp 178-180

VASIL'EV, A. N. and GALUBEV, V. V., Gor'kiy

[Abstract] A planar problem is solved arising when a circular cylinder moves through a rectangular channel without touching the walls of the channel. It is considered that the disturbed movement of the fluid caused by the motion of the cylinder arises from the state of rest. The hydrodynamic forces acting on the cylinder are calculated. Figures 2, references 5 Russian.  
[167-6508]

UDC: 532.528

#### SYSTEM OF DEVELOPED CAVITATION FLOW AROUND WEDGE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 1, Jan-Feb 83 (manuscript received 20 Apr 81) pp 165-170

BEKULOV, M. T., Nal'chik

[Abstract] A plan is suggested for the study of a symmetrical steady flow around a wedge in a channel with developed cavitation in an ideal incompressible, weightless fluid. The plan combines existing cavitation flow systems around bodies and describes a flow which is intermediate between flow around obstacles as suggested by Ryabushinskiy and Efros. The results of the

calculation are presented in tabular form, indicating that the drag and cavity dimensions depend on the cavitation number. As the cavitation number increases the drag increases while the dimensions of the area of cavitation decrease. Figures 3, references 3 Russian.  
[167-6508]

UDC: 533.696:533.6.011.5

#### SUPERSONIC FLOW AROUND A THIN CONE WITH NONAXISYMMETRIC NODES

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 1, Jan-Feb 83 (manuscript received 13 Jul 81) pp 144-419

VISHNEVETSKIY, S. L. and IVANOV, M. A., Moscow

[Abstract] A study is made of some of the specifics of three dimensional flow on the example of flow around circular cones with small aperture angle and various nose shapes. The noses are all conical, though the aperture angle is different from that of the main cone and the tip of the nose cone is not at the center of the main cone. The body is assumed to be stationary, the incident gas flow uniform. The asymmetric nose shape causes significant pressure gradients as well as gradients in other parameters. The effect of the nose cone extends beyond the area of the cone itself. Experimental data on the pressure distribution over the surface of the main cone are presented in graphic form. Experimental and calculated results agree satisfactorily. Figures 4, references 9: 6 Russian, 3 Western.  
[167-6508]

UDC: 533.6.071

#### PROBLEM OF MODELING OF HYPERSONIC FLOW AROUND BODIES IN WIND TUNNELS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 1, Jan-Feb 83 (manuscript received 3 Jun 80) pp 125-130

ALFEROV, V. I. and VITKOVSKAYA, O. N., Moscow

[Abstract] A study is made of modeling of hypersonic flow conditions in various types of wind tunnels. Hypervelocity flow around objects is distinguished by a number of characteristics resulting from the influence of the actual properties of the gas, including a significant decrease in the distance of separation of the shock wave, absorption of the entropy layer by the boundary layer and changes in chemical composition of the gas. Studies are performed in wind tunnels with resistive heating, wind tunnels with electric arc heating, wind tunnels providing natural values of stagnation enthalpy and wind tunnels with natural flow velocities. Conditions of modeling of flow around an object are analyzed from the standpoint of reproducing natural conditions and chemical composition of the gas. The

problem of modeling hypervelocity conditions in wind tunnels is quite pressing and far from its solution. Of all of the installations studied the most suitable from the standpoint of reproducing actual flight conditions are installations which reproduce the natural values of velocities such as wind tunnels with magnetogas-dynamic gas acceleration. Figures 2, references 18: 9 Russian, 9 Western.  
[167-6508]

UDC: 533.6.011.5

#### PROFILING OF AXISYMMETRIC AND FLAT NOZZLES PRODUCING A RADIAL SUPERSONIC FLOW

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 1, Jan-Feb 83 (manuscript received 24 Jun 81) pp 118-124

KRAYKO, A. N., and SHELOMOVSKIY, V. V., Moscow

[Abstract] Profiling of axisymmetric nozzles is begun by determining the properties of radial flow of a nonviscous, nonheat-conducting gas with both planar and axial symmetry. In profiling of flat configurations the radial flow is considered planar. Equations are obtained which allow the characteristics of the flow to be constructed in the meridional plane. The nozzles constructed are interesting in both theoretical and practical respects. In the radial nozzle final acceleration of the flow occurs due to expansion of the channel and radial flow away from the axis of symmetry. In the flat or sector nozzles the walls are meridional planes. The number of walls depends on the Mach number of the flow. Profiled walls of the optimal configurations are constructed by a method outlined in previous works by the same authors. Figures 5, references 9 Russian.  
[167-6508]

UDC: 535.5

#### BODY OF MINIMAL WAVE RESISTANCE IN A TWISTED HYPERSONIC FLOW

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 1, Jan-Feb 83 (manuscript received 4 Aug 81) pp 107-117

OSTAPENKO, N. A., Moscow Institute of Mechanics, Moscow State University

[Abstract] A study is made of flow around a body in a cylindrical system of coordinates in which the x axis coincides with the direction of translational movement of the incident flow and is the axis of rotation of the flow. A body of minimal resistance is sought in the class of surfaces with similar transverse cross sections along the x axis. It is found that a thin

body of minimum wave resistance with zero moment relative to the longitudinal axis in a twisted flow has a transverse contour with symmetrical cycles. Its resistance related to the resistance of an equivalent body of rotation with the same longitudinal contour coincides with the resistance of an optimal body in a nontwisted flow. Figures 5, references 7: 6 Russian, 1 Western.  
[167-6508]

UDC: 532.526

THEORETICAL AND EXPERIMENTAL STUDY OF VISCOUS FLUID FLOW NEAR LINE OF INTERSECTION OF CYLINDRICAL AND FLAT SURFACES

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 1, Jan-Feb 83 (manuscript received 4 Jun 81) pp 64-68

GUREVICH, Yu. G., Moscow

[Abstract] A study is made of longitudinal flow of incompressible nonheat-conducting fluid around a corner formed by the intersection of a bent cylindrical surface with a plane. The presence of heat conductivity should not qualitatively influence the pattern of flow produced in the analysis. The results show that curvature of one of the intersecting surfaces qualitatively does change the flow pattern near the corner. The boundary layer within which viscosity is significant has a more complex structure than near a dihedral angle. Its thickness decreases with decreasing distance from the line of intersection of the surfaces to a value on the order of  $Re^{-2/3}$ , the transverse velocity in this area being on the order of  $Re^{-1/3}$ . Figures 4, references 7: 4 Russian, 3 Western.  
[167-6508]

UDC: 533.6.011.5

SPATIAL SUPERSONIC FLOW OF AN IDEAL GAS AROUND A FINNED BODY

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 1, Jan-Feb 83 (manuscript received 25 Mar 81) pp 185-187

ROZIN, A. V., Moscow

[Abstract] Results are presented from numerical and experimental studies of a steady supersonic flow of a nonviscous nonheat-conducting ideal gas with adiabatic index 1.4 around a body of revolution with plus- and X-shaped ribs with incident velocity  $M_\infty = 3$ . An Euler equation system is integrated numerically. A steady supersonic analog of a Godunov system is used as a finite difference approximation. The outer boundary of the calculated area is the head shock wave, the inner boundary is the surface of the body. The

calculations determine that the presence of fins at the stern of the body does not influence the position of the head shock wave near the nose cone. The increment in the normal force coefficient arising on a body of revolution due to fins is approximately an order of magnitude less than the normal force coefficient acting on the fins. Figures 2, references 12: 11 Russian, 1 Western.  
[167-6508]

UDC: 533.6.011.5

#### PENETRATION OF JET BLOWN THROUGH CONVEX CYLINDRICAL SURFACE INTO SUPERSONIC FLOW

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 1, Jan-Feb 83 (manuscript received 16 May 81) pp 187-190

ZAKHARCHENKO, V. F., KARDANOV, Yu. Kh. and SEMENIKHIN, A. N., Moscow

[Abstract] Data are presented from optical experimental studies of longitudinal flow of a supersonic air stream around a cylinder in a wind tunnel with cold air jets blown through circular apertures perpendicular to the surface of the body. Shadow photographs were used to measure the distance from the body surface to a hanging compression shock, the maximum distance from the body and the central point of closure of the shock. The results showed that within the range of  $I=0.0035-0.15$ , the value of  $Z_c$  for circular apertures of relatively small diameter and longitudinal slots agree satisfactorily. The polar angles of points in the wave structure of the injected jets depend only on the intensity of the injection. Figures 3, references 3: 2 Russian, 1 Western.  
[167-6508]

UDC: 533.6.011.72

#### EXACT SOLUTION OF PROBLEM OF GAS COMPRESSION BY SPHERICAL SHELL

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Nov-Dec 82 (manuscript received 7 Apr 81) pp 176-179

SVALOV, A. M., Moscow

[Abstract] A study is made of the problem of isentropic gas compression by a spherical shell of finite thickness sharing an external boundary with a vacuum. The full solution of the problem can be achieved only numerically. However, there is a class of exact solutions of gas dynamic equations with linear distribution of particle velocities by radius in which contact discontinuities can exist. An example of the exact solution describing the process of compression for which the initial and final states are the

substance at rest with constant pressure distribution and density is presented. It is determined that the assigned compression ratio, identical for the entire substance, can be achieved in an arbitrary number of compression cycles. Figures 2, references 2 Russian.  
[168-6508]

UDC: 533.6.011.5

CONFIGURATION OF SUBSONIC ZONES ARISING UPON SUPERSONIC FLOW AROUND A SPHERICALLY BLUNTED CYLINDER AT HIGH ANGLES OF ATTACK

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Nov-Dec 82 (manuscript received 16 Apr 81) pp 174-176

MINOSTSEV, V. B. and SAVINOV, K. G., Moscow

[Abstract] A method is presented for calculation of the flow on the windward side of a cylinder with a spherical tip for the case when there are local or extended subsonic areas along the lateral surface of the body. There are five types of flow around such a body, depending on the angle of attack. An example of calculation of flow around a specific cylinder for  $M_0=6$ ,  $\gamma=1.4$  is presented. Figures 2, references 3 Russian.  
[168-6508]

UDC: 533.6.011.35

DISTANT NONLINEAR FIELD WITH TRANSSONIC FLOW AROUND A NONLOAD-BEARING PROFILE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Nov-Dec 82 (manuscript received 23 Mar 81) pp 171-173

SEVOST'YANOV, G. D., Saratov

[Abstract] A new analytic solution is obtained to the nonlinear transsonic equations describing the distant vortex-free flow field generated by transsonic flow around a nonload-bearing profile. Figures 2, references 5: 2 Russian, 3 Western.  
[168-6508]



UDC: 533.6.011:518.5

APPROXIMATE SOLUTION OF NON-SELF-SIMILAR PROBLEM OF MOVEMENT OF PISTON AFTER BRIEF IMPACT

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Nov-Dec 82 (manuscript received 30 Apr 81) pp 167-171

USTINOV, M. D., Minsk

[Abstract] This article obtains an approximate solution to the problem of the movement of a piston after a brief impact of gas pressure, assuming a small parameter  $\varepsilon$  equal to the initial velocity of the piston divided by the speed of sound in the gas at rest. In the problem specifically addressed, a piston in a cylinder is accelerated by an impact in the direction of the portion of the cylinder containing a gas. It is assumed that there is a vacuum on the other side of the cylinder. After a time the piston stops and then begins to move in the opposite direction due to the increase in gas pressure ahead of the piston. Figure 1, references 3 Russian. [168-6508]

UDC: 533.6.011:697

CALCULATION OF THREE-DIMENSIONAL TRANSSONIC GAS FLOW THROUGH AXIAL TURBINE STAGE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Nov-Dec 82 (manuscript received 5 Mar 81) pp 138-146

GNESIN, V. I., Kharkov

[Abstract] A three-dimensional transsonic flow of a nonviscous, nonheat-conducting gas through one stage of an axial turbine including stationary guide vane assembly and runner rotating at a constant angular velocity is studied in the physical region. Aerodynamic interactions between the guide vane assembly and runner are considered. The principle used is that of determining the complete system of unsteady three-dimensional equations of motion of the gas through the system of vanes. The greatest nonuniformity of parameters is found to occur in the root sections downstream from the guide vanes. Figures 4, references 16: 12 Russian, 4 Western. [168-6508]

## RADIATION OF INTERNAL WAVES UPON RAPID HORIZONTAL MOTION OF CYLINDERS AND SPHERES

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Nov-Dec 82 (manuscript received 18 Jun 81) pp 94-100

GORODTSOV, V. A. and TEODOROVICH, E. V.

[Abstract] When analyzing the radiation of internal waves by moving bodies, they are frequently modeled as a set of sources and sinks and mass dipoles. It is usually assumed that calculations by this method lead to satisfactory results even in slightly stratified fluids at high velocities. This method, though universal, has paradoxical aspects. For example, the loss of energy in the three-dimensional problem with horizontal motion is infinite. The pressure and other characteristics on the wake are also singular. This work presents a universal analytic method for describing the field of internal waves based on approximate surface distribution of sources, which become exact solutions of the integral equations and exact models of bodies in a homogeneous fluid. References 15: 11 Russian, 4 Western.  
[168-6508]

## STREAM FLOW OF AN IDEAL FLUID AROUND A FLEXIBLE SHELL

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Nov-Dec 82 (manuscript received 19 May 81) pp 43-48

ZHITNIKOV, V. P. and TEREENT'EV, A. G., Ufa, Cheboksary

[Abstract] A soft cylindrical shell is studied, attached at two points. Flow separation occurs at an intermediate, third point. The velocity of the fluid is constant and equal to the velocity at infinity throughout the section of the shell over which the flow is attached. The fluid is considered ideally incompressible and weightless. It is proven that steady flow is possible only with  $\mu$  greater than a certain critical value, where  $\mu = 2(P_0 - P_\infty) / \rho v_\infty^2$ ,  $P_0$  is pressure inside the shell,  $P_\infty$  is the pressure of the fluid at infinity,  $\rho$  is the density of the fluid, and  $v_\infty$  is the velocity of the flow at infinity. As  $\mu$  increases the steady flow loses stability and the process becomes unsteady. No experimental confirmation is presented. Figures 5, references 7: 6 Russian, 1 Western.  
[168-6508]

## APPROXIMATE CALCULATION OF AERODYNAMIC CHARACTERISTICS OF SHORT CYLINDRICAL BODY IN INCOMPRESSIBLE FLOW

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNICA in Russian No 4, Oct-Dec 82 (manuscript received 23 Mar 82) pp 65-69

PASTUKHOV, A. I. and DERYABIN, A. D.

[Abstract] Determination of the influence of profile shape of a short cylindrical body on aerodynamic characteristics is important for many applied problems. The authors solve this problem by replacing the body of cylindrical shape with an aerodynamically equivalent infinite wing with a profile of the same shape. The mid-section of the cylindrical body is replaced by a vortex surface of attached vortices with intensity constant over span, continuously distributed with a certain density over the chord of the mid-plane. Straight infinite free vortices oriented at an angle to the chord of the plate extend from the ends of the attached vortices. The distribution of circulation over span is assumed constant, its value equal to the circulation in the middle (root) section of the plate. Results from conversion of the lift of an NACA-0016 profile for a cylindrical body with a span of  $\lambda=0.2$  and calculation of the center of pressure are presented along with experimental data. Figures 3, references 3 Russian.  
[180-6508]

## CRITICAL FLUTTER SPEED OF FIN WITH RUDDER

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNICA in Russian No 4, Oct-Dec 82 (manuscript received 1 Apr 81) pp 61-64

PAVLOV, V. A. and CHERNIKOV, S. K.

[Abstract] An earlier article suggested a three dimensional calculation plan for a fin with a rudder allowing precise description of the elastic properties of the structure. This article utilizes this plan to study the influence of frontal rigidity of the rudder on the critical flutter speed. It is assumed that the stabilizer works only in bending in the plane of least rigidity while the rudder, rigid to twisting, bends in both the normal and frontal planes. An equation system is derived which can be used to calculate the critical flutter speed and frequency of oscillations of the fin in a flow of incompressible gas for various values of frontal rigidity. A graph is presented illustrating the influence of this characteristic on critical speed. Figure 1, references 2 Russian.  
[180-6508]

STABILITY ANALYSIS OF AUTOMATIC BALANCER

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 2, Feb 83 (manuscript received 10 Nov 81) pp 19-23

ZAKRZHEVSKIY, M. V., doctor of technical sciences, professor, and  
TURONOK, F. I., senior instructor

[Abstract] The performance of an automatic balancer on the rotor of any machine subject to vibrations due to rotor unbalance is analyzed on the basis of a dynamic model of the system. The main object is to establish the pull-in region and, accordingly, the initial conditions which will ensure stability of balance. The rotor is a stiff structure with given mass  $m_0$  and eccentricity  $e$  mounted horizontally and symmetrically in elastoviscous dissipative bearings and spinning at a certain constant angular velocity. In its plane of symmetry are attached two mathematical pendulums, each of mass  $m$  and length  $L$ . Their motion relative to the rotor is accompanied by both dry and viscous friction. The corresponding equations of motion in dimensionless form include three terms accounting respectively for gravity forces acting on the pendulums, external drag forces resisting their motion, and dry friction forces. The condition for balancing is established first, whereupon the pull-in region is determined in the plane of angular coordinates of the pendulums. The effect of drag and friction on the magnitude of the pull-in region is evaluated on the basis of calculations with all these factors disregarded, with each of these factors included along and several values assigned to the characterizing coefficients, and with all factors combined. The results reveal that an initial velocity must be imparted to the pendulums, in order to achieve balancing, this velocity depending on pull-in region. Figures 3, references 3 Russian.  
[175-2415]

## AXISYMMETRIC HARMONIC VIBRATIONS OF PIEZOCERAMIC SHELLS OF REVOLUTION

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 12, Dec 82 (manuscript received 17 Jul 81) pp 115-118

GOLOLOBOV, V. I., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] The piezoelectricity problem is solved for thin piezoceramic shells of revolution. Such a shell vibrates upon application of an alternating voltage to electrodes assumed here to completely cover both inside and outside surfaces. These vibrations are analyzed according to the theory of thin shells, with conventional hypotheses of shell mechanics, and on the basis of appropriate equations of electro-statics. The electric field distribution over the shell wall is expressed in the form of a series in functions of the thickness coordinate, assuming a uniform wall thickness and a thickness polarization of the electric field. After all equations have been linearized accordingly, relations between electrical parameters (electric induction) and mechanical parameters are obtained which yield the sought system of first-order ordinary differential equations of motion. These are solved for given boundary conditions pertaining to forces and moments, linear and angular displacements, and electric potential or charge at the end faces of the shell. Results have been obtained for a cylindrical shell made of PZT-4 material without mechanical load and without electric charge at the end faces, 0.0222 m in diameter and 0.0333 m long with 0.003175 m wall thickness. Figure 1, references 6: 5 Russian, 1 Western.  
[172-2415]

UDC: 534.26

## INTERACTION OF PLANE STEADY ACOUSTIC WAVE AND CYLINDRICAL SHELL HINGE-MOUNTED ON STIFF HALF-SPACE

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 12, Dec 82  
(manuscript received 14 Dec 81) pp 111-114

OVSYANNIKOV, A. S., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] The diffraction problem is solved for a steady acoustic wave at an infinitely long semicylindrical shell hinge-mounted on an acoustically stiff half-space. The wave field in the acoustic medium is characterized as the sum of four potentials: potential of the incident wave, potential of the wave reflected by the plane boundary of the half-space, velocity potential of the wave scattered by the shell, and potential associated with vibrations of the shell. These vibrations are described by the Muskhelishvili-Donnell-Vlasov equations of motion, assuming the vibrations to be harmonic. The solution yields the bending moment on the shell as well as normal and tangential displacements. A numerical solution is obtained by the Bubnov-Galerkin variational-difference method, with piecewise-linear approximation of the bending moment as well as of the displacements of the median surface over the shell circumference (semicircle). Figures 4, table 1, references 9 Russian.  
[172-2415]

# OPTIMIZATION OF REINFORCED CYLINDRICAL SHELLS FOR CARRYING LOCAL LOADS ON BASIS OF STRENGTH CRITERION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 18, No 12, Dec 82  
(manuscript received 4 Aug 81) pp 41-47

MAKSIMENKO, V. P., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] Optimization of reinforced cylindrical elastic shells for carrying local loads is treated as a problem of mathematical programming, namely minimizing the weight function within a given space of many variables. Calculations are based on the V. Z. Vlasov engineering theory of thin shells and the corresponding equations in finite-difference form for each of the four panels around a point of intersection of a stringer and a hoop. With the forces and stresses determined accordingly, the optimum weight is calculated on the basis of strength for given parameters of the shell material and boundary conditions. The maximum stress at the corner points of each panel is also calculated, by a conventional method, whereupon the entire problem can be reduced to the canonical form of linear programming. The method has been applied to a cylindrical shell with eight stringers and a hoop at each end, under the load of four longitudinal cyclically symmetric compression forces distributed each over a  $30^\circ$  arc around the circumference. Figure 1, table 1, references 14: 12 Russian, 1 Polish, 1 Western.  
[172-2415]

UDC: 539.3:678.5-419.8.06

# STRESSED-STRAINED STATE OF PRESSURE TANK MADE OF COMPOSITE MATERIAL WITH ELASTIC INTERLAYER BETWEEN SHELL AND FLANGE

Kiev PRIKLADNAYA MEKhanika in Russian Vol 18, No 12, Dec 82  
(manuscript received 10 Sep 81) pp 36-40

NIKITYUK, V. A., Moscow oblast

[Abstract] A pressure tank is considered, a shell of revolution made of a composite material with an elastic interlayer between shell and flange. The tank consists of a helically wound layer and a hoop wound around it, both wound with tape of an orthotropic reinforcing material with given mechanical characteristics. The flanges are placed inside the port holes and fastened to the shell by an elastic interlayer, both holes are covered with lids. The state of stress and strain under internal pressure is analyzed with particular attention paid to shearing forces introduced by the elastic interlayers. The corresponding boundary-value problem, a system of six first-order linear differential equations, takes into account geometric nonlinearity as well as the nonlinear dependence of shearing forces on the clearance between shell and flange beyond the interlayer. The problem is solved by

quasi-linearization of the trigonometric terms characterizing internal forces and simple iteration of the nonlinear algebraic terms representing external forces. The entire solution process reduces to an iteration through successive approximations, with discrete orthogonalization according to the Runge-Kutta method. The procedure has been programmed in FORTRAN for a YeS-1022 Unified System computer. Numerical results for a typical tank reveal that elastic interlayers lower the maximum stresses around the port holes but increase the axial displacement of the lids, in comparison with free support of the flanges (shear modulus  $G = 0$ ). Figures 3, references 5 Russian.

[172-2415]

UDC: 539.3

#### AXISYMMETRIC STRESSED STATE OF NEARLY SPHERICAL THICK-WALLED ELASTIC SHELLS

Kiev PRIKLADNAYA MEKhanika in Russian Vol 18, No 12, Dec 82  
(manuscript received 22 Dec 81) pp 18-24

NEMISH, Yu. N., LYALYUK, D. F. and CHERNOPISKIY, D. I., Institute of Mechanics, UkSSR Academy of Sciences, Kiev; Ivano-Frankovsk Institute of Petroleum and Gas

[Abstract] The stressed state of nearly spherical thick shells under internal pressure or centrifugal forces (in rotation) is analyzed by the method of boundary perturbation. Eight symmetric variants of such shells are considered: either the inside surface or the outside surface spherical and the other aspherical (variable thickness), and both surfaces oval with their major and minor axes either collinear (uniform thickness) or orthogonal (variable thickness). The aspherical surface is described by the equation  $r = r_1 \pm \epsilon f(\theta)$  ( $r = R/r_0$ ,  $r_1 = r_0'/r_0$ ,  $r_0$  - radius of nominal inside sphere,  $r_0'$  - radius of nominal outside sphere,  $\epsilon$  - amplitude of deviation from nominal sphere,  $\theta$  - latitude angle,  $f(\theta)$  - continuous and differentiable  $2\pi$ -periodic function). The problem is solved for isotropic shells and transversely isotropic shells, the latter rotating at constant angular velocity about the polar axis. Numerical calculations have been made by an iteration process on a BESM-6 high-speed computer for  $\epsilon = 0.1$  and the Poisson ratio of the material  $\nu = 0.25$ , with the thickness parameter  $r_1$  varied from 1.3 to 2, yielding the distribution of meridional and circumferential as well as normal stresses. The convergence of the solution by successive approximations is found to improve as  $r_1$  increases. Figures 3, tables 3, references 7 Russian.

[172-2415]

## ELASTOPLASTIC STATE OF SOLIDS OF REVOLUTION UNDER VARIABLE NONISOTHERMAL LOADING WITH CREEP

Kiev PRIKLADNAYA MEKhanika in Russian Vol 18, No 12, Dec 82  
(manuscript received 24 Jun 82) pp 12-17

SAVCHENKO, V. G., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] The axisymmetric stressed state of a solid of revolution with arbitrary shape of the meridional section is considered under conditions of nonsteady heating and variable loading by surface and body forces. These forces, as well as the ambient temperature and the heat transfer coefficient are known functions of the space coordinates and of time. Their time dependence is such that the temperature field satisfies the differential equation of heat conduction with boundary conditions of the third kind and that the thermoplasticity problem can be treated in the quasi-steady approximation. Mechanical and thermophysical properties of the material are temperature dependent. The problem is solved in a cylindrical system of coordinates, with loading and heating processes subdivided into successive stages matching changes in the direction of deformation of individual body elements as a result of loading-unloading reversals. Solution of the problem involves determination of the temperature at points of the body, stresses  $\sigma_{zz}, \sigma_{rr}, \sigma_{\phi\phi}, \sigma_{zr}$ , strains  $\epsilon_{zz}, \epsilon_{rr}, \epsilon_{\phi\phi}, \epsilon_{zr}$ , and displacements  $u, w$  at successive fixed instants of time. Loading along a rectilinear and along a slightly curvilinear deformation trajectory is considered, the time and temperature dependence of shearing stress and shear strain intensities assumed not to depend on the state of stress so that they can be determined from test data on simple tension-compression of cylindrical specimens. Creep during unloading of body elements is taken into account, but secondary plastic deformation is disregarded. Figures 5, references 4 Russian.  
[172-2415]

UDC: 534.14.621.822.6

## PARAMETRIC VIBRATIONS OF ROTOR MOUNTED IN BALL BEARINGS

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 2 Aug 81, after completion 17 Dec 81) pp 75-81

BURMISTROV, A. N. and GALAKHOV, M. A., Moscow

[Abstract] A system of differential equations of motion is derived for a rotor mounted in ball bearings, taking into account variability of radial and axial as well as torsional stiffness. The rotor is assumed to be in a nearly horizontal position and to rotate at constant speed together with the inner races. The array of balls in each bearing is assumed to revolve at



constant angular velocity without friction at the races, and the outer race is assumed to be stationary. The equations are derived by the Lagrange method of kinetic and potential energy, with the aid of a Taylor series expansion for the potential energy of a ball. Purely radial and purely axial parametric vibrations are considered, purely torsional vibrations being analogous to purely radial ones, and conditions for resonance in the fundamental (strongest) mode at a frequency equal to twice the angular velocity of the balls are established in each case. In the case of radial parametric vibrations the roots of the characteristic equation are found to be either one positive real and the other not, or both imaginary so that beats occur. In the case of axial parametric vibrations there are also possible either resonance or beats. An analysis of a practical case reveals that resonance in axial vibrations could be prevented by sufficiently reducing the amplitudes of certain space harmonics of waviness of the outer bearing race. This has been confirmed experimentally. References 4 Russian. [170-2415]

UDC: 621.822.5

#### SOLUTION OF TRANSIENT PROBLEM OF LUBRICATION IN CONICAL HYDROSTATODYNAMIC BEARINGS

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 7 Jan 82, after completion 16 Aug 82) pp 94-100

TOKAR', I. Ya. and KHAYSAROV, R. Z., Kharkov

[Abstract] The problem of lubrication in hydrostatodynamic bearings under transient conditions is solved analytically for a conical bearing, assuming a turbulent steady flow of low-viscosity fluid in the clearance. The corresponding averaged Reynolds equations in Cartesian coordinates are integrated with the aid of Prandtl hypotheses, observing the conditions of continuity of shearing stress at the laminar sublayer boundary and zero shearing stress at the center of the channel (centerline of lubricant layer). The equations are reduced to quasi-linear ones, the coefficients characterizing the flow conditions are evaluated for given instants of time or for given iterations, and the solution is obtained for the pressure. Calculations have been checked experimentally on a stiff rotor mounted in conical bearings. The hydro-dynamic parameters were determined from its equations of motion, after derivatives with respect to time have been converted to finite differences and the equations in this form solved either by the Euler method with inertia forces disregarded or by the Newton method with inertia forces taken into account. The rotor was set in motion by an electric motor through a gear box. Vertical and horizontal displacements of the shaft near bearings, axial load and movement, pressure in the feed channel cavities, and rotor speed were measured as functions of time. Both measurements and calculations reveal relaxation effects in the lubricant film; zero-crossovers of axial force and axial eccentricity do not coincide in time. Figures 4, references 3 Russian. [170-2415]

## NATURAL VIBRATIONS OF MULTISPAN REGULAR GIRDERS OF SHELLS-OF-REVOLUTION TYPE

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 1, Jan 83 (manuscript received 28 Jun 82) pp 45-49

GROMYKO, O. V., graduate student, and POPOV, A. Yu., engineer

[Abstract] Modes and frequencies of natural vibrations of a multispans regular shells-of-revolution girder are calculated on the basis of a hypothetical multilayer continuous structure analogous to a densely spaced discrete structure with equivalent deformation or kinetic energy of the smallest repeatable element. The matrix of elasticity constants in the generalized Hooke's law  $\{\sigma\} = [B_j] \{\epsilon\}$  for each shell layer containing  $m$  beam elements is analogous to that matrix for an anisotropic material. Internal forces and moments are related to strains through components of the membrane stiffness tensor, the flexural stiffness tensor, and the membrane-flexural stiffness tensor averaged over the stack thickness. The dimensions of a beam element are assumed to be a few orders of magnitude smaller than the overall girder dimensions. The analysis becomes simpler when a repeatable element has one to three planes of symmetry so that the variables can be separated not only with respect to time but also with respect to the circumferential coordinate. The resulting equation for the  $m$ -th harmonic is solved by the S. K. Godunov method of orthogonal elimination. Quasi-transverse and quasi-tangential vibration modes have been calculated by this method for tetrahedral free girder consisting of open (0.86 rad arc) spherical shells, each a grid of beam elements made equally long of the same material. Figure 1, table 1, references 7 Russian. [174-2415]

## PARAMETRIC VIBRATIONS OF STRAIGHT HOSES

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 1, Jan 83 (manuscript received 19 May 82) pp 41-45

BALAKIREV, A. N., student, and SAGINADZE, I. S., engineer

[Abstract] Parametric vibrations of a straight hose carrying to full capacity an ideal viscous incompressible fluid with velocity and pressure fluctuations is analyzed, considering that a hose represents the extreme case of a pipe with almost zero flexural and torsional stiffness. The fluid velocity and pressure each consist of a constant component and a harmonically alternating one, conforming to given boundary conditions, the alternating components of velocity and pressure being mutually orthogonal in time. The fundamental equation of small vibrations is reduced to a dimensionless one with periodically varying coefficients. Vibration modes are determined from the virtual

work principle, with both displacement and first variation of displacement represented as sums of Fourier sine series and only the first two terms retained. The stability region is established according to the approximate Rayleigh method. A comparison with results based on the exact numerical Floquet method indicates that the Rayleigh method is completely accurate as long as the amplitude of the alternating velocity component remains much smaller than the constant velocity component. Figures 3, references 3 Russian.  
[174-2415]

UDC: 620.10

#### PARAMETRIC VIBRATIONS OF BEARING HOUSING AND SHAFT

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 1, Jan 83 (manuscript received 18 May 82) pp 37-40

STARZHINSKIY, V. M., doctor of physico-mathematical sciences, professor, and KVARTIN, L. M., candidate of technical sciences

[Abstract] A bearing housing for a vertical shaft rests on three elastic shock absorbers spaced  $120^\circ$  apart. The shaft is slightly unbalanced by a mass at the free end which bends it to a certain amount of eccentricity. Vibrations of the bearing housing caused by the shaft unbalance are analyzed according to the theory of parametric resonances in nearly canonical systems. For this purpose, the two equations of motion for the shaft in the Lagrange form of the second kind are first reduced to homogeneous equations and then to a single vector equation. The solution to the latter is examined and reveals that neither the two fundamental-frequency resonances nor the difference-frequency resonances occur, but it yields a double inequality defining a wide single range of instability. Calculations for and model experiments with VTK spindles confirm these conclusions. For design and operation, therefore, it is necessary to check all resonances. Figure 1, references 2 Russian.  
[174-2415]

## LOAD CAPACITY OF CYLINDRICAL SHELL UNDER PURE BENDING

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 1, Jan 83 (manuscript received 17 Dec 81) pp 28-33

LOKOSHCHENKO, A. M., candidate of physico-mathematical sciences, and  
PECHENINA, N. Ye., graduate student

[Abstract] A long circular cylindrical shell of a thickness much smaller than the radius is considered under a bending moment, with no other forces acting on it. The symmetry of the problem makes it permissible to deal with one quadrant of the cross section only. Under load a quadrant of the shell contour is approximated with arcs of two circles of different radii, one with the center on the x-axis and one with the center on the y-axis, joining at some point within the quadrant. In effect, the curvature and thus the strain of the shell under load have increased along the two arcs with smaller radius and decreased along the two arcs with larger radius of the quasi-ellipse. The problem of behavior during loading is solved first for a shell made of a linearly elastic material, assuming piecewise-uniform distribution of axial forces over the cross section, and the result reveals that the points of collocation do not shift significantly during the bending process. In the case of a nonlinearly elastic material the shell is regarded as consisting of double-layer longitudinal and transverse elements independently responding to deformation. In this case, too, the collocation points do not shift appreciably and can be regarded as stationary. The results are compared with the N. J. Hoff solution. Figures 3, references 6: 4 Russian, 2 Western. [174-2415]

UDC: 531.0(075.8)

## ELASTOPLASTIC EQUILIBRIUM OF THICK-WALLED HOLLOW CYLINDER MADE OF NONMOGENEOUS MATERIAL

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 1, Jan 83 (manuscript received 22 Mar 82) pp 6-11

ANDREYEV, V. I., candidate of physico-mathematical sciences, docent, and  
SHIPILOVA, Ye. Ye., graduate student

[Abstract] A long thick-walled cylinder made of an ideally plastic material is considered under uniform internal and uniform external pressure. The equation of balance for stresses and the condition of compatibility for strains are formulated in a polar system of coordinates, assuming polar symmetry, and are supplemented with Cauchy equations relating strains to radial displacement. The problem of equilibrium is solved on the basis of Hooke's law for the elastic zone and the Huber-Mises criterion for plasticity.

Solution of the equations for an incompressible material yields the pressure at which plastic deformation begins and the radius of the boundary separating the plastic zone from the elastic one. The results reveal that increasing the pressure reduces the effect of material nonhomogeneity on displacements. Figures 3, references 7: 6 Russian, 1 Polish.  
[174-2415]

UDC: 534.11

# IDENTIFICATION OF STIFFNESS OF SHAFT SUPPORTS IN BEARING ASSEMBLIES

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 22 Sep 81, after completion 23 Mar 82) pp 21-26

KUDINOV, V. A., KOCHINEV, N. A. and SAVINOV, Yu. I., Moscow

[Abstract] A mathematical model of a shaft on bearings is constructed for calculating the stiffness of each support. If a load force  $P_j$  is applied at  $L$  points and the displacement (strain)  $q_i$  is measured at  $m$  points on the

$$q_i = \sum_{j=s_1}^{s_L} \delta_{ij} P_j \quad (\delta_{ij} - \text{influence factors, } i = 1, 2, \dots, m, j = s_1, s_2, \dots, s_L).$$

This model is transformed into an equivalent one by removing all supports except two and replacing them with reactions at these two fictitious ones  $R_{r1,2} = -q_{r1,2} \Delta C_{r1,2}$ , where  $\Delta C_{r1,2} = C_{r1,2} - C_{r1,2}^f$  ( $C_{r1,2}$  - true stiffness of supports 1,2;  $C_{r1,2}^f$  - fictitious stiffness of supports 1,2). The stiffness of the shaft itself is assumed to be known from design data. The resulting system of algebraic equations of force balance with fictitious influence factors is solved by conventional methods for the unknown stiffnesses  $C_s$  and stiffness decrements  $\Delta C_s$ . The method has been tested on an example of a shaft on four bearings and checked for accuracy against measurements made with a shaft successively on four, three, and two bearings. A practical application is machine tools. In an experiment with a lathe on two double-row cylindrical roller bearings (No 3182120 at front end and No 3182122 at rear end) the stiffness of supports was determined first by measurement of strains (displacements) under a 7000 N load applied with a contactless electromagnetic device and then, after disassembly of the lathe, by measurement of clearance-interference fits between shaft and bearings. Figures 5, tables 2, references 4 Russian.  
[170-2415]

## VIBROSHOCK RESONANCES IN SYSTEMS WITH RANDOM PARAMETRIC PERTURBATION

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 29 May 81) pp 16-20

KOVALEVA, A. S., Moscow

[Abstract] The response of a vibroshock system with one degree of freedom to random parametric perturbation is analyzed by a method involving the perturbed periodic Green function for a linear system with such a perturbation. The problem is reduced to a second-order homogeneous differential equation of motion and the solution for the displacement as a function of time is obtained in the form of an integral of the product of the driving function by the Cauchy function for the system, the integral from  $-\infty$  to  $t$  for an asymptotically stable system and minus the integral from  $t$  to  $\infty$  for an unstable system. This solution is transformed to describe the steady-state motion under small perturbations, approximately a  $T$ -periodic single-shock motion with small fluctuations. Its essential feature is the fundamental periodic mode, resonance, the conditions for which with balance of nonconservative forces are established by the energy method. References 6 Russian.  
[170-2415]

UDC: 539.37;534.29

## EFFECT OF HIGH-FREQUENCY VIBRATION ON PROCESSES OF PLASTIC DEFORMATION

Moscow MASHINOVEDENIYE in Russian No 2, Mar-Apr 83 (manuscript received 31 Aug 82) pp 3-12

ASTASHEV, V. K., Moscow

[Abstract] Various technological processes which involve plastic deformation and cutting of material utilize the softening effect of high-frequency vibration, namely the reduction of the amount of static force necessary for achieving a given result, ultrasonic treatment being a typical example. This effect has been studied in many experiments with testing under static and dynamic loads. Here the anomalous behavior of materials in an ultrasonic field is analyzed on the basis of rheological models of elastoplastic bodies subject to shock and the complete equation of motion for the loading tool  $u(t) = vt + u_0(t)$  ( $u$ - displacement,  $u_0(t) = \alpha \sin \omega t$ ,  $v$ - velocity,  $\alpha$  - acceleration,  $t$ - time). The static deforming force is calculated as a function of tool displacement and velocity in the material, with properties of the latter (yield strength) and characteristics of the test specimen or product sample (stiffness) as parameters of this relation. The relation between static deforming force and strain rate under a pulse load and under a continuous load

is established, involving the parameters of vibration as well as the yield strength of the material. This relation takes into account the counter-effect of plastic deformation on the vibration mode. The results of this analysis are particularly applicable to nonferrous metals such as aluminum, magnesium, copper, also brass. Figures 6, table 1, references 19: 15 Russian, 4 Western.  
[170-2415]

UDC: 539.3:534.1

#### CIRCUMFERENTIAL PROPAGATION OF HARMONIC WAVES IN PIEZOCERAMIC SHELLS OF REVOLUTION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 30 Sep 81) pp 123-126

GOLOLOBOV, V. I. and POLOVINKINA, I. B., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] Circumferential propagation of harmonic waves in a thin piezoceramic shell of revolution is analyzed, assuming the material to be polarized in the direction of the outward normal to the surface and the surface electrodes to be closed in themselves. The three-dimensional problem is reduced to a two-dimensional one, with the elasticity relations for pure flexure under a transverse load derived from the thermoelasticity relations and applied here in an approximation based on Kirchhoff-Love hypotheses. The electric potential at the electrodes appears in one term of the expressions for the moduli of elasticity. The eigenvalue problem for the corresponding system of eighth-order ordinary differential equations is solved for wavelength and frequency of each mode, with each contour of the shell either load-free or rigidly clamped. Homogeneous boundary conditions yield the dispersion equation. An analysis of wave excitation in a closed shell yields the relation between wave motion and resonant vibrations. A polyphase voltage generator is required for excitation of traveling waves, a typical example being excitation of a short circular cylindrical shell with a two-phase voltage generator. Figure 1, references 9: 8 Russian, 1 Western.  
[171-2415]

## THERMALLY STRESSED STATE OF BODIES OF PARABOLOIDAL SHAPE AND FINITE DIMENSIONS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 1, Jan 83  
(manuscript received 30 Sep 80) pp 120-122

SKRIPKA, V. I., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] Thermal stresses in solid and hollow paraboloids of finite dimensions, bounded by paraboloidal coordinate surfaces, are calculated for the case of approximately aerodynamical nonuniform heating. The problem, in the quasi-static formulation for a body with surfaces free of external loads, is solved assuming first that a cavity does not affect the temperature field. On this basis a solution is obtained for a solid paraboloid and then for a hollow one, with appropriate boundary conditions, the results revealing a zone of large tensile stresses in both. Their states of thermal stress differ only along the cavity and within a thin surface layer around it. Figures 3, references 3 Russian.  
[171-2415]

## NONLINEAR VIBRATIONS OF SLIGHTLY ASYMMETRIC ELASTIC SYSTEMS WITH MANY DEGREES OF FREEDOM

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 1, Jan 83  
(manuscript received 14 Oct 80) pp 101-108

POKROVSKIY, L. N., Moscow Evening Institute of Metallurgy

[Abstract] Nonlinear vibrations of asymmetric structures consisting of membranes and shell panels or of guy ropes with many degrees of freedom are analyzed on the basis of a general system of coupled differential equations. This system is solved by the "small parameter" method for specific initial conditions, without restriction on the number of generalized coordinates. The procedure is based on asymptotic methods and takes into account that the coefficients which characterize the asymmetry are functions of the curvature, approaching zero as the latter does. A solution is obtained for the case of small asymmetry coefficients, corresponding to a nearly symmetric and flat elastic panel part of the structure, assuming first that the structure is without internal resonances and then that there is a  $\omega_i = 2\omega_k$  kind of internal resonance. The solution describing steady forced nonlinear vibrations at a single frequency under a harmonic load, including attenuation, is reduced to the corresponding solution for a symmetric structure. As an example, a system of four second-order nonlinear differential equations has been solved by the Bubnov-Galerkin method for a net of guy ropes and its amplitude-frequency characteristics. Figures 2, references 10 Russian.  
[171-2415]



## BUCKLING OF BEAM UNDER COMPRESSION AND TORSION BEYOND ELASTIC LIMIT

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 27 Jun 80) pp 82-88

DAVYDOV, V. S., Zonal Scientific Research and Design Institute for Standard and Experimental Design of Residential and Communal Buildings

[Abstract] The behavior of a circular cylindrical rod under a compound compression and torsion load after simple preloading is analyzed, assuming that the compression force and the twisting moment each act in a constant direction. The critical compression force and twisting moment are determined, namely those at which a contiguous infinitesimally close to trivial equilibrium mode in buckling beyond the elastic limit is still possible. The problem is solved for an incompressible material, according to the theory of small elastoplastic strains and on the basis of the "plane sections" hypothesis, assuming simple subcritical strains at all points. In the case of buckling along a three-dimensional curve under compression or torsion one cannot a priori, but only after solution of the problem, assume that simple loading continues within an infinitesimal vicinity of the bifurcation point and then apply a certain theory of plasticity. If the theory of two-stage elastoplastic processes is used, then the corresponding stability problem for the rectilinear equilibrium mode under compression and tension can be reduced to two transcendental equations with two unknown constants. Figures 3, references 13: 12 Russian, 1 Western.  
[171-2415]

## DYNAMICS OF VIBRATION-ISOLATED FOUNDATIONS UNDER MACHINES AND OTHER EQUIPMENT

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 2 Jun 80) pp 67-71

IVOVICH, V. A., Central Scientific Research Institute of Building Structures, Moscow

[Abstract] The dynamic behavior of vibration-isolated foundations under machines and other equipment is analyzed, for design purposes, by the method of transfer matrices. The vibrating equipment is assumed to move horizontally, vertically, and rotationally. Relations in the form of matrix equations are established for simultaneous flexural and longitudinal vibrations of a perfectly rigid rectangular beam segment on a kinematically excited continuous elastic base as model, at  $i$  sections along the beam span. Harmonic horizontal and vertical concentrated forces acting at  $i$  points along the

beam span and moment acting at one end are considered as a specific case. As an example, the frequencies of natural axial, transverse, angular vibrations and the amplitudes of corresponding displacements have been calculated by this method for a typical foundation under a vertical column. Figures 5, references 3 Russian.  
[171-2415]

UDC: 62-222:539.4

STRESSED STATE OF DOUBLE-LAYER CYLINDRICAL SHELL RESULTING FROM ASSEMBLY OF COMPONENT SHELLS WITH DEVIATIONS FROM CIRCULAR SHAPE

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 1, Jan 83  
(manuscript received 23 Sep 80) pp 52-58

CHERNOV, B. P., Scientific-Industrial Association for Study and Design of Power Equipment imeni I. I. Polzunov, Leningrad

[Abstract] Hot shrinking of individual shell layers without pretreatment is an economical method of assembling multilayer cylindrical housings. Each layer is a cylindrical shell with some inevitable manufacturing deficiency which results in a nonuniform initial circumferential stress distribution in the final structure, with flexural stresses superposing on bond stresses produced by a uniform interference fit. Here the state of stress and strain under an arbitrary normal load is determined for a cylindrical ring with arbitrary deviations from circularity. The problem is solved in Fourier series by the Rayleigh-Ritz method. The contact pressure is determined from the condition that the difference between the deflections of coupled shell layers must be equal to the interference fit at every point on the contact surface. An experimental study was made with a batch of double-layer shells (length 500 mm, wall thickness 12.4 mm, inside diameter of outer shell 1023 mm, outside diameter of inner shell 1024 mm). The results of measurements were evaluated by harmonic analysis and checked against theoretical calculations. The necessary algorithms have been programmed in FORTRAN-4 for a YeS-1020 Unified System digital computer. Computations were made by engineers D. B. Biryukov, L. V. Piven' and T. B. Tuzova. Figures 2, tables 2, references 11: 10 Russian, 1 Western.  
[171-2415]

## ULTIMATE CONCENTRATED LOAD APPLIED TO SHELL AT ARBITRARY POINT

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 22 Oct 80) pp 47-51

DEKHTYAR', A. S. and KOTOVA, L. B., Kiev State Art Institute

[Abstract] Shallow shells of uniform thickness and rectangular in the plan view are considered with arbitrary constraints at the edges and with a median surface which can have a positive, negative, or alternating Gaussian curvature. The shell material satisfies the generalized Johansen condition of plasticity. Determining the upper limit of the ultimate load, a concentrated force, applied at any point of the shell is treated as a variational problem  $K_* = \min_{U, V, W} (D_1 E^{-1})$  ( $K = Q/\sigma$   $b^2$  dimensionless ultimate load,  $Q$ -total load,

$\sigma$  - yield point in tension,  $2b$ - shorter span,  $D_1$  - dissipation of internal energy,  $E$ - power of external load,  $\dot{U}, \dot{V}, \dot{W}$  kinematically admissible fields of displacement rates), the latter reduced to minimization of a function of several variables, and solved by the method of a discretization grid. The configuration of  $W(x, y)$  fields is sought as the product of two functions describing Gaussian probability distributions. The problem is solved first for a load acting at the center and then for special cases of shells with translational surfaces in the shape of an elliptic or hyperbolic paraboloid made of a material with different yield points in tension and in compression. Calculations reveal a wide range within which the load capacity depends neither on the point of load application nor on the mode of edge constraints. Numerical results have been obtained for shells made of reinforced concrete and shells made of a material with compressive strength equal to tensile strength, for shells on hinge supports. Figures 4, tables 2, references 9 Russian.

[171-2415]

## ELASTOPLASTIC STATE OF LAMINATE-WOUND CYLINDRICAL SHELL UNDER INTERNAL PRESSURE

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 21 Oct 81) pp 41-46

IL'IN, L. A. and LOBKOVA, N. A., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] A laminate-wound cylindrical shell made of an ideal elastoplastic material is considered and its elastoplastic state of stress and strain under internal pressure is calculated for the case of a large friction coefficient  $f \geq \frac{\ln 2}{2\pi}$ . Circumferential forces are determined from the equations of

equilibrium and integral relations for sectors of slip and adhesion. The integration constants are evaluated according to a corresponding system of transcendental (logarithmic-exponential) expressions. The behavior of such a shell under increasing pressure, namely the redistribution of elastic and plastic zones, is tracked on this basis. An expression is derived for the critical pressure, which corresponds to yield in the narrow overlap sector built up with an extra layer between fixed inner and outer end. Calculations are shown for a shell consisting of five layers with an overlap angle  $\alpha = 0.22$  rad and a friction coefficient  $f = 0.2$  under three successively higher pressure levels. Figures 2, table 1, references 5 Russian.  
[171-2415]

UDC: 539.3

#### STABILITY OF REINFORCED THIN CONICAL SHELLS

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 5 Oct 81) pp 36-40

GAVRILENKO, G. D., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] A design of reinforced thin conical shells for stability is shown, with calculations based on a zero-moment uniform subcritical state taking into account the discrete spacing of reinforcement members. The joints between sheath and reinforcement allow for longitudinal strain, deflections of sheath and reinforcement are assumed to be equal. Linearized equations of mixed kind are obtained by application of the Lagrange virtual work principle to the total potential strain energy. These equations have been solved numerically by the Bubnov-Galerkin method for conic frustum shells with a regular array of reinforcing hoops and stringers under uniform compression. Calculation of the critical load has been programmed in FORTRAN-4 for an M-4030 or YeS 1040 Unified System computer. Results are shown for such a shell with one hoop at the center and eight stringers. Figure 1, table 1, references 5: 4 Russian, 1 Western.  
[171-2415]

UDC: 539.3

#### NUMERICAL SOLUTION OF AXISYMMETRIC PROBLEMS IN DYNAMICS OF THIN ORTHOTROPIC SHELLS OF REVOLUTION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 14 Jul 80) pp 31-35

VALIULLIN, A. Kh., Kazan Institute of Chemical Technology

[Abstract] Equations of axisymmetric motion in displacements are formulated for a thin shell of revolution according to nonlinear theory for large deflections (of the order of the wall thickness). Problems of dynamics are

solved by the method of finite differences with a meridian subdivided into  $n$  segments of equal length, which requires a special subroutine for meridians of arbitrary form. Three boundary conditions must be stipulated at each edge, any combination of four kinds (rigid clamping, fixed hinging, movable hinging, no constraint). The algorithm for solving the resolvent system of algebraic equations, with all time derivatives converted to finite differences, has been programmed in FORTRAN for a YeS 1033 Unified System computer. These equations are linear not only for linear problems but also for nonlinear ones, inasmuch as the displacements in nonlinear terms have already been determined in previous steps of the solution for two preceding instants of time. References 6 Russian.  
[171-2415]

UDC: 539.3

#### BEHAVIOR OF SHELLS OF REVOLUTION DURING AXISYMMETRIC DEFORMATION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 7 Jul 80) pp 24-30

PIKUL', V. V., Institute of Automation and Control Processes, Far-Eastern Science Center, USSR Academy of Sciences, Vladivostok

[Abstract] A thin-walled flexible shell of revolution with a circular hole at the pole is considered under axisymmetric deformation. Its state of stress and strain is calculated in different systems of coordinates most suitable for any given part of the problem. Displacements are calculated for a meridional beam-strip of infinitesimal width on the basis of the corresponding system of one-dimensional equations. The resulting solution to the problem of shell behavior is transformed to a Gaussian system of coordinates. The solution is then used for calculating the effect of a perfectly rigid washer tightly inserted into the center hole of a thin spherical shell under uniform internal pressure on circumferential, tangential, and flexural stresses. The edge effect and its rate of asymptotic decrement are evaluated in terms of stress concentration, and compared with the stress concentration factor for a nonreinforced hole. Figures 3, table 1, references 10 Russian.  
[171-2415]

UDC: 539.3:534.1

#### STABILITY OF FLEXIBLE SHALLOW SHELLS IN TEMPERATURE FIELD

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 19 Aug 80) pp 16-23

VAKHlayeva, L. F. and KRYS'KO, V. A., Saratov Polytechnic Institute

[Abstract] Flexible shallow shells rectangular in the plan view are analyzed for stability under load in a temperature field, assuming that their material

obeys Hooke's law and its elastic properties are not temperature dependent. The closed system of differential equations for the static problem, with a steady temperature field, consists of two two-dimensional equations of thermoelasticity and one three-dimensional equation of heat conduction. They are solved by the difference method with a fourth-order approximation scheme and by the iteration method of nonlinear relaxation. The boundary conditions and the compatibility conditions are stipulated, generally in an appropriate approximation. On the basis of the general solution, stability calculations have been made for isotropic shells under transverse load in a temperature field. The results confirm that the stability pattern is not significantly affected by thermal insulation of the lateral surfaces but is strongly affected by thermal insulation of the bottom base. The deflection curve and the reaction force depend in large measure on the thermal moment and the thermal force at the boundary respectively. Figures 4, references 5 Russian.  
[171-2415]

UDC: 539.3

#### LINEAR THEORY OF THIN SHELLS ON BASIS OF 'ASSOCIATED VECTORS' CONCEPT

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 1, Jan 83  
(manuscript received 31 Oct 80) pp 10-15

KAYUK, Ya. F. and ZHUKOVSKIY, A. P., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] A correspondence is established between kinematic quantities and between equations of equilibrium according to a linear theory of thin shells based on the concept of associated vectors and according to classical theories such as the Timoshenko theory respectively. The new variant of linear theory is shown to provide a standard and more general method of deriving conventional relations as well as for establishing new ones. References 5: 3 Russian, 2 Western.  
[171-2415]

UDC: 539.52

#### LOAD CAPACITY OF BEAM STRUCTURES MADE OF MATERIALS WITH LIMITED PLASTICITY

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 2, Feb 83  
(manuscript received 24 Nov 80) pp 120-123

BACHINSKIY, V. Ya. and MANISKEVICH, Ye. S., Scientific Research Institute of Building Structures, Kiev

[Abstract] The method of ultimate equilibrium, widely used in the design of building structures, is reassessed with regard to plasticity of the material. The standard assumption of infinite plasticity is replaced with the realistic

premise of limited plasticity. A continuous statically indeterminate beam made of a perfectly rigid material with short elastoplastic "hinge" segments is taken as model and its behavior under a uniformly distributed load is analyzed, assuming either an idealized stress-strain curve (elastic limit = yield point) or an ideally elastoplastic material (infinite ultimate strain). The equation of moments and deflections yields in each case the critical load under which two consecutive "hinges" work both elastically, one elastically and one elastoplastically, and both elastoplastically. Moment-load curves and load-deflection curves are calculated accordingly. Numerical results confirm the proposition that limited plasticity of the material such as high-strength or medium-strength concrete must be taken into account in design calculations.

[173-2415]

UDC: 539.3

'PERIODIC' SOLUTION OF ELASTICITY PROBLEM FOR AXISYMMETRIC DEFORMABLE ELASTIC PARABOLOID OF REVOLUTION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 2, Feb 83  
(manuscript received 4 Oct 80) pp 118-120

SKRIPKA, V. I., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] Solutions to the elasticity problem for an axisymmetric deformable elastic paraboloid of revolution are considered, one solution being expressed in the form of two probability density functions with Hankel integrals and another one being "periodic" in the form of Fourier-Bessel series. A valid analogy between both solutions is established here for "periodic" deformation of a paraboloid of finite length with displacements of the boundary surface described by a complete system of orthogonal Hankel functions, "periodic" deformation being mathematically analogous to symmetric deformation of a body with a purely harmonic spectrum of eigenfunctions at the boundary surface but have no specific physical significance. References 3 Russian.

[173-2415]

UDC: 534.2:532

FORCED VIBRATIONS OF CYLINDRICAL SHELL IN ACOUSTIC WEDGE

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 2, Feb 83  
(manuscript received 10 Apr 81) pp 113-118

POTAPOV, M. A. and SHUL'GA, N. A., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] A solid cylinder inside a coaxial thin cylindrical shell is emitting sound into a wedge of an acoustic medium around it. The acoustic

medium inside the shell around the radiator is not necessarily the same as the acoustic medium outside the shell within the wedge. The acoustic field outside the shell within the wedge is calculated by integration of two corresponding scalar Helmholtz equations for the given regions and two equations of motion for the thin cylindrical shell, with appropriate boundary conditions at the surface of the radiator, conditions of coupling at the median surface of the shell, and boundary conditions at the wedge surfaces. Solution of the boundary-value problem by the method of images, in a cylindrical system of coordinates with origin on the axis of both cylinders, ensures that the boundary conditions at the two wedge surfaces are satisfied automatically. The radiation pattern, angular distribution of the modulus of sound pressure, has been evaluated numerically for a fiberglass shell in water contained in a wedge with perfectly stiff boundaries. The results reveal that wedging imparts directionality to the radiation pattern, increasingly so as the shell with radiator moves closer to the corner of the wedge. The nonuniformity of the radiation pattern is least along the wedge angle bisector on the open side of the shell. Figures 4, references 9 Russian. [173-2415]

UDC: 539.377:532.72

# VARIATIONAL EQUATIONS OF THERMODIFFUSION IN DEFORMABLE THIN SHELLS WITH FINITE STIFFNESS IN SHEAR

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 2, Feb 83  
(manuscript received 24 Nov 80) pp 83-88

SHVETS, R. N. and RAVRIK, M. S., Institute of Application Problems in Mechanics and Mathematics, UkSSR Academy of Sciences, L'vov

[Abstract] A generalized variational principle is proposed for thermodiffusion and fundamental equations describing the interdependence of deformation, heat conduction, and diffusion processes are derived from it for thin shells with finite stiffness in shear. Thin transversely isotropic shells of uniform thickness in nonuniform temperature and concentration fields are considered, these fields evolving as a result of either heat and mass transfer between shell and ambient medium or as a result of shell deformation. Displacements and strains according to the appropriate shear model are inserted into the functional  $K_0$  in the diffusional theory of deformation, where-upon a theorem is established for this functional about the equation  $\delta K_0 = 0$  being equivalent to a closed system of differential equations of mechanothermodiffusion for such shells under a set of natural (contour) boundary constraints. From this variational equation are derived other principles, specifically M. A. Biot's principle for thermodiffusion. Analogs of Castigliano's and Lagrange's principles can also be derived from it. References 12: 9 Russian, 3 Western. [173-2415]



## EXPERIMENTAL STUDY OF STABILITY OF REINFORCED SPHERICAL SHELLS UNDER EXTERNAL PRESSURE

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 2, Feb 83  
(manuscript received 17 Sep 81) pp 52-57

GRACHEV, O. A. and PAL'CHEVSKIY, A. S., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] An experimental study was made concerning the stability, under external pressure, of reinforced spherical shell segments with a ratio of riser height to base circle diameter not exceeding 1/5. The material was 0.6 mm thick sheet of VT1-0 titanium alloy for one batch and 0.7 mm thick sheet of Kh18N10T stainless steel for another batch. There were four series of titanium shells (smooth, reinforced only with uniformly spaced 16, 14, or 32 meridional angle beams of the same material spot welded to the outside surface), four series of steel shells (smooth, reinforced only with uniformly spaced angle rings of D-16 aluminum alloy riveted to the inside surface), and three series of doubly reinforced steel shells (3 rings and 24 or 32 beams, 5 rings and 32 beams). The shells were mounted in a vessel on the table of a hydraulic press between retaining collars. They were tested under pressure not exceeding 70% of the critical level and all lost stability within the elastic range of the material, in the form of one depression in the smooth shells or several depressions in the reinforced shells with an attendant sound effect. The critical pressure was calculated according to the relation  $\eta = \frac{q(R)}{E(h)}^2$  ( $q$ - actual pressure,  $E$ - modulus of elasticity,  $R$ - radius of base circle,  $h$ - height of riser). A general conclusion can be drawn from the results of this experiment, namely that reinforcing beams and rings can not only bend or twist under external pressure but also simultaneously bend and twist. Figures 6, table 1, references 8: 5 Russian, 3 Western.  
[173-2415]

## NONAXISYMMETRIC BUCKLING OF DEEP ELASTIC SHELLS OF REVOLUTION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 2, Feb 83  
(manuscript received 7 Jul 80) pp 45-51

BERMUS, I. M. and SRUBSHCHIK, L. S., Rostov State University

[Abstract] The loss of stability by thin shells of revolution in various equilibrium modes is determined according to the J. L. Sanders theory for finite deflections. Deep shells with continuous surface are considered under axisymmetric load, and finite asymmetric displacements are calculated on the basis of dimensionless nonlinear equations. The boundary-value

problem for the corresponding system of three second-order ordinary differential equations, which always has an axisymmetric solution, is reduced to an operator equation whose solution is a maximizable vector function in Banach space. It is solved by numerical integration according to Newton's method with matrix elimination and with continuation in the load parameter. The results have been checked against those obtained by the much longer method of ranging and against experimental data, for a spherical shell under external pressure. The axisymmetric solution remains stable for small loads, but can become nonaxisymmetric as the load increases. The solution to a system of four linear second-order equations in this case reveals that the critical load is almost independent of the rotation of a surface element about a normal. Tables 4, references 16: 11 Russian, 5 Western. [173-2415]

UDC: 539.3

#### METHOD OF DISCRETE APPROXIMATION OF FUNCTIONAL IN STABILITY PROBLEMS FOR SHELLS OF REVOLUTION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 2, Feb 83  
(manuscript received 11 Jan 82) pp 38-44

BABICH, D. B., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] The stability problem for a symmetric multilayer shell is solved by the finite-difference method with discrete approximation of the functional in the Trefftz variational principle. The coordinate outline surface of the shell is generated by a smooth curve rotating about some axis. The material is linearly elastic, orthotropic, and pliant in shear so that transverse shear strains must be taken into account. The wall thickness and the elastic properties of the material can vary meridionally, the external load is assumed to be axisymmetric. The problem is solved by application of the Trefftz variational principle to a three-dimensional elastic multilayer body, with subsequent reduction to a two-dimensional problem and then to a one-dimensional one. The difference scheme, replacing the integral with central rectangles in quadratures and the derivatives with finite differences of high-order precision, ensures fast convergence and high accuracy with conservation of the properties of the differential equations. The resolvent Ritz equations, with static boundary conditions eliminated automatically and geometric boundary conditions satisfied exactly, are solved through a system of algebraic equations with a symmetric strip matrix. The algorithm, including elimination by the Gauss method, has been programmed in ALGOL-60 for a BESM-6 high-speed computer. The algorithm is demonstrated on the calculation of critical loads for cylindrical, spherical, and conical shells under hydrostatic pressure. Tables 2, references 10 Russian. [173-2415]

## FREE VIBRATIONS OF PRESTRESSED CYLINDRICAL SHELL OF VARIABLE THICKNESS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 2, Feb 83  
(manuscript received 8 Sep 80) pp 33-37

KUKUDZHANOV, S. N., Tbilisi Institute of Mathematics, GSSR Academy of Sciences

[Abstract] Free vibrations of medium-length and long closed elastic cylindrical shells with variable wall thickness under either external or internal pressure are analyzed, the lowest frequencies being most important and most sensitive to thickness variation. The problem is solved by the method of successive approximations with Schwarz constants for a wall thickness varying only longitudinally but according to any arbitrary law, specifically a power law with maximum or minimum thickness at the center as special cases. The equations of motion in radial displacements for a prestressed shell rigidly clamped at both ends are based on the zero-moment theory, considering that longitudinal waviness is negligible in comparison with circumferential waviness. The solution to these equations must and does satisfy four boundary conditions, two at each end, for axial components and the condition of circumferential periodicity. Figures 4, references 5 Russian.

[173-2415]

## FREE VIBRATIONS OF REINFORCED CYLINDRICAL SHELL WITH PERFECTLY SOLID BODY ON INTERMEDIATE SUPPORTS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 2, Feb 83  
(manuscript received 23 Dec 81) pp 28-32

PALAMARCHUK, V. G., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] A closed circular cylindrical shell reinforced with a regular array of stringers and hoops carries a perfectly solid body hinge to it inside at points spaced uniformly along two generatrices and symmetrically with respect to the longitudinal diametral plane containing the center of mass of the body. The structure is hinge-supported at both ends as well as at intermediate points uniformly spaced along two generatrices. Free vibrations of such a structure are analyzed, assuming zero longitudinal reaction forces at the hinge joints and the hinge supports and negligible inertia forces in the tangential plane. The reinforcement grid is sufficiently dense for disregarding the terms in the equations of motion which contain products of two harmonics in the series, the one associated with the number of reinforcement members having a negligible effect on the most important lower frequencies. These assumptions have been validated by solution of the problem without them for a shell with a rigidly attached mass.

The problem is solved for small vibrations of the body relative to its equilibrium position, the deflection function for the shell sought in the form of a double trigonometric series and the stress function found from the solution to the equation of compatibility for strains. It is solved by the energy method, with the expressions for kinetic energy and total potential energy inserted into the corresponding Lagrange equation of the second kind. Calculations for a specific shell and body system reveal that the lowest frequency of natural vibrations increases as the joints between shell and body are located farther from the crest of the harmonic which corresponds to the lowest natural frequency of the shell alone. Figures 3, references 5 Russian.  
[173-2415]

UDC: 539.3

# APPLICATION OF CHEBYSHEV POLYNOMIALS TO PROBLEMS OF INTERACTION BETWEEN THICK-WALLED ELASTIC SPHERE AND ACOUSTIC MEDIUM

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 2, Feb 83  
(manuscript received 29 Nov 80) pp 21-27

GALAZYUK, V. A. and GORECHKO, A. N., L'vov State University

[Abstract] The transient problem of interaction between a thick-walled elastic sphere and an acoustic medium is solved by the method of Chebyshev-Laguerre polynomials. There is an acoustic medium inside and outside the sphere, pressure waves assumed to act on either surface. The resulting motion of the wall is described by a system of Lamé differential equations in a spherical system of coordinates, which in the axisymmetric case resolves into two scalar wave equations for the bulk strain. This system of equations is solved simultaneously with the equation of a perturbed pressure field inside or outside. The solution in the form of an orthogonal series in Chebyshev-Laguerre polynomials is convergent for piecewise-continuous initial and boundary conditions. In the case of zero initial conditions with boundary conditions of continuous contact between elastic solid sphere and ideal compressible fluid the problem reduces to infinite sequences of ordinary differential equations containing coefficients of a series in Legendre and Laguerre polynomials. Normal and tangential displacements upon impact by a plane step wave of pressure from outside have been calculated by this method for a hollow steel sphere and, for comparison, for a solid one. Figures 5, references 7 Russian.  
[173-2415]

## STRESS-STRAIN STATE OF ORTHOTROPIC MULTILAYER SHELLS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 1, Jan-Feb 83 (manuscript received 24 May 81) pp 155-166

UL'YASHINA, A. N., Moscow

[Abstract] A study is made of the theory of heterogeneous orthotropic shells in which transverse deformation coefficients are considered. A kinematic model can be constructed by the theory as presented to determine the distribution of movement through the thickness of the shell so that a mixed system of equations can be derived to solve the system in a manner which satisfies all initial three-dimensional equations normally considered in such problems. The method involves assigning 8 geometric or 8 static boundary conditions around the edge of the shell, corresponding to 16th order equations. Application of the theory to circular cylindrical shells is analyzed. Figures 6, references 9 Russian.  
[169-6508]

UDC: 539.3:534.1

## GEOMETRIC THEORY OF SHELL STABILITY

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 1, Jan-Feb 83 (manuscript received 18 Mar 82) pp 143-154

GOL'DENVEYZER, A. L., Moscow

[Abstract] A shell is studied, the edges of which are under homogeneous, self-conjugate conditions assuring that the work of edge forces is zero. It is assumed that it is loaded by a surface load. The stress-strain state caused by the load is described by tangential force tensors, moments, shear forces, tangential and normal displacements, tangential and flexural deformations. The influence of flexural deformations on the asymptotes of maximum and minimum critical loads is studied. It is found that the nonlinear problem of supercritical equilibrium of the shell within the framework of the theory of large bends can be identified with the linear problem of the stress-strain state evoked by an arbitrary load assigned by an equation presented in the text and an additional load related to the nonlinear components, for which the equation is also presented. The "click deformation", for which a closed rib which disrupts smoothness develops, is studied for a surface of positive curvature. Figures 2, references 12 Russian.  
[169-6508]

OPTIMUM DESIGN OF RIGID PLASTIC BEAMS WITH STEPWISE CONSTANT HEIGHT UNDER PULSED LOADING

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 1, Jan-Feb 82 (manuscript received 18 Mar 82) pp 136-142

LEPIK, Yu. R., Tartu

[Abstract] A beam is studied with freely supported ends and cross section which varies in steps. The beam is rigid-plastic with rectangular cross section, the center portion of the beam being thicker than the two ends, which are of equal cross section. The equations of motion for the beam under impulsive loading are derived and integrated. Simple results are obtained, though the method could be extended to more complex cases of beam shape and loading. Examples are presented, illustrating several sample computations performed by computer. Figures 6, references 14: 7 Russian; 7 Western.

[169-6508]

SOLUTION OF SINGULAR PROBLEMS OF TWISTING ELASTIC-IDEALLY PLASTIC ROD

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 1, Jan-Feb 83 (manuscript received 17 Mar 82) pp 102-106

PROTSENKO, A. M., Moscow

[Abstract] A study is made of the problem of singular solutions from the standpoint of the theory of an elastic-ideally plastic body for which stresses must satisfy the plasticity condition. This means that the stresses at all points in the cross section must be limited. Singular internal stress fields are found, indicating that the stress field is regular. The energy dissipated in a loading cycle is calculated. This allows the number of cycles until fatigue failure occurs to be computed. References 4 Russian.

[169-6508]

## OPTIMAL SHAPE OF REINFORCED COLUMN GROWING AT RANDOM SPEED

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 1, Jan-Feb 83 (manuscript received 24 Feb 81) pp 91-101

KOLMANOVSKIY, V. B. and METLOV, V. V., Moscow

[Abstract] A study is made of a reinforced column of a fixed volume and height made of a viscoelastic material with the properties of creep and aging. The cross sections of the column are geometrically similar, differing only in dimensions. Assuming that the rate with which the column height is increased by the addition of new sections is a random process, the problem is to find a column profile for which the mean value or mathematical expectation of movement of the upper section is minimal. Equations are derived which solve the problem in parametric form. It is found that the optimal shape of the column depends on the rate at which the column height increases. Further, the optimal column shape differs for random and deterministic rates of height increase. With random growth, the cross-sectional area changes more uniformly, as a result of probabilistic averaging. Figures 5, references 10: 9 Russian, 1 Western.  
[169-6508]

UDC: 624.131+539.215

## STRESS STATE OF POROUS FLUID-SATURATED HALF SPACE WITH EXTERNAL DISTRIBUTED PRESSURE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 2, Mar-Apr 83 (manuscript received 17 Jul 81) pp 172-178

ZAZOVSKIY, A. F., Moscow

[Abstract] A study is made of a porous, homogeneous and isotropic half space saturated with a compressible fluid. It is assumed that a certain quasistatic axisymmetrical pressure distribution is instantaneously created, maximal at the axis and vanishing outside a certain defined area, applied simultaneously to both the solid phase and the fluid filling the pores. The stress state of the half space and the possibility of rupture are studied by repeated application of Laplace-Hankel transforms. The influence of pressure in the pores on the strength characteristics of the medium and location of the rupture area is studied. Figures 8, references 11: 5 Russian, 6 Western.  
[187-6508]

## CONTACT PROBLEMS OF DISCRETE INTERACTION OF PLATE AND ROD

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 2, Mar-Apr 83 (manuscript received 22 Jun 81) pp 160-171

RYBAKOV, L. S., Moscow

[Abstract] A study is made of a planar elastic system consisting of an unlimited thin plate and a homogeneous rod connected by rivets. The rod makes an angle with the abscissa and may be infinite, semiinfinite or finite in length, the rivets being located at a constant spacing along the rod's axis. The approach to solution of the problem considers the elasticity of rivets, damage to the rod and rivets, initial technological imperfections and other factors which influence the combined deformation of the plate and the rod. Figures 3, references 10: 9 Russian, 1 Western.  
[187-6508]

## NATURAL OSCILLATIONS OF INHOMOGENEOUS VISCOELASTIC BODIES

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 2, Mar-Apr 83 (manuscript received 11 May 81) pp 117-123

MAIBORDA, V. P. and TROYANOVSKIY, I. Ye., Moscow

[Abstract] A study is made of a compound body consisting of  $N$  volumes, each of which is filled with a viscoelastic medium, the parameters of which vary from volume to volume. The zero displacements are set on a portion of the surface, zero stresses on another portion, and there are no mass forces. The task is to determine the frequency and damping index of the natural oscillations of the body. The natural oscillations are determined for heterogeneous viscoelastic systems with a finite number of degrees of freedom. The system consists of a finite number of material points and absolutely rigid bodies interconnected by massless viscoelastic elements. If the structure of the system is homogeneous and the rheologic characteristics of the elements are identical, the system is a finite-dimensional model of a homogeneous system with distributed parameters. The natural oscillations of a multilayer cylinder are also determined. The cylinder consists of  $N$  coaxial viscoelastic layers. Figures 3, references 5 Russian.  
[187-6508]



# BEHAVIOR OF SOLUTIONS OF DYNAMIC PROBLEMS AT EDGE OF CRACK MOVING WITH TRANSSONIC VELOCITY IN ELASTIC MEDIUM

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 2, Mar-Apr 83 (manuscript received 14 Oct 81) pp 109-116

SIMONOV, I. V., Moscow

[Abstract] The asymptote of solutions near the edge of a crack moving at transsonic velocity in an elastic medium is studied. An exact solution is found for the problem of transsonic motion of a crack for both directions of motion under the influence of a moving load and a load applied to the edges of the crack. The solution is obtained by analyzing the canonical planar problem of flow of an elastic medium around a semiinfinite crack. Motion is assumed steady. The problem is reduced to the solution of two equations in an unlimited plane with a crack for the longitudinal and transverse movement potentials. References 6: 5 Russian, 1 Western. [187-6508]

# FLIGHT SIMULATION ALGORITHM FOR DYNAMIC SUPPORT-TYPE TEST STAND

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 2, Mar-Apr 83 (manuscript received 14 Jul 82) pp 30-37

ALEKSANDROV, V. V., DYLEVSKIY, I. V., ZIMENKOV, V. D., TIKHANINA, I. G. and CHUGUNOV, O. D., Moscow

[Abstract] A study is made of the problem of simulating flight on a supported dynamic flight trainer with 6 degrees of freedom. The platform performs limited motions by changing the length of 6 electrohydraulic cylinders connected between the platform and the foundation by ball joints. Considering the reaction of the human vestibular system, the components of the motion of an actual flight vehicle which must be simulated to produce a realistic sensation of flight are determined. The algorithm implementing flight simulation is described. Figures 4, references 8 Russian. [187-6508]

## PROBLEM OF DETERMINING LOAD-BEARING CAPACITY OF GLASS REINFORCED PLASTIC AIRCRAFT PROPELLOR BLADE

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 82 (manuscript received 10 Jun 81) pp 95-99

ZAYTSEV, G. P. and SILANT'YEV, S. A.

[Abstract] A two bladed propeller with a Klark-y profile made of VM-78 glass reinforced plastic with EDT-10P epoxy binder with reinforcement angle  $+15^\circ$  is studied. The purpose of the study is to determine the load-bearing capacity of the blade under short-term and cyclical loadings and to select the optimal reinforcement angle from the standpoint of maximum strength reserve. Analysis of the data obtained shows that under static loads the optimal reinforcement angle is  $+37^\circ$ , while under cyclical loading the optimal angle is  $+5^\circ$ . Figures 3, references 7: 4 Russian, 3 Western. [180-6508]

## STABILITY CALCULATION OF SPHERICAL IMPERFECT SHELL BASED ON REFINED BULGING PATTERN

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 82 (manuscript received 2 Jul 81) pp 89-92

TEREGULOV, A. G.

[Abstract] The following plan is suggested for stability calculation of shells of imperfect form: the most dangerous initial imperfection in the form of an individual dent such as those formed during bulging is fixed; subcritical elastic bending is assigned as a development of the initial dent under the influence of the load in the form of an individual characteristic dent with the accompanying attenuating wave state. The problem of subcritical bending is then solved. The value of subcritical elastic bending obtained is then substituted into the stability equation written considering the subcritical moment state occurring due to development of the initial irregularity. Critical bending is assigned in the form similar to the expression for subcritical elastic bending. This approach allows additional definition to be included in the method of stability calculation of shells of imperfect form, consequently allowing the production of more reliable values of upper critical loads. The method is most effective in those cases when a bulge on the surface of a shell forms a large number of projections in both directions. The numerical results obtained in a study of the stability of a cylindrical shell compressed along its axis show that the method suggested allows close approximation to experimental data. References 6: 5 Russian, 1 Western. [180-6508]

## OSCILLATIONS OF SMOOTH SHELL WITH ATTACHED MASS DISTRIBUTED OVER PART OF SURFACE

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 4, Oct-Dec 82 (manuscript received 2 Nov 81) pp 16-20

ANTUF'YEV, B. A.

[Abstract] The problem of harmonic oscillation of a thin elastic curved shell panel with an attached mass distributed over the surface of the shell in a sector of arbitrary shape is solved in its contact statement. The natural and forced harmonic oscillations of the thin shell are computed. The attached mass is considered as an elastic inclusion of variable rigidity. Figures 2, references 6 Russian.  
[180-6508]

UDC: 539.3

## CALCULATION OF STRESSES ON SURFACE OF ELASTIC BODY

Kiev PROBLEMY PROCHNOSTI in Russian No 2, Feb 83 (manuscript received 3 Oct 80) pp 102-104

ADLUTSKIY, V. Ya., Dnepropetrovsk State University

[Abstract] An algorithm is presented for computation of the stresses on the surface of a body on the assumption that the displacements and loads are known at discrete points on the surface, obtained experimentally or based on solution of the edge problem by one of the network methods. The accuracy of computation increases with increasing power of the approximating polynomial. Examples are presented of calculation of the surface stresses of a cylinder in torsion and in extension with a circular hole. Figures 3, references 3: 2 Russian, 1 Western.  
[178-6508]

UDC: 620.178.2

## TECHNOLOGY OF MANUFACTURE AND STRENGTH COMPUTATION OF CYLINDRICAL EQUAL STRENGTH COMPOSITE SHELLS OBTAINED BY DIFFUSION SATURATION

Kiev PROBLEMY PROCHNOSTI in Russian No 2, Feb 83 (manuscript received 23 Feb 82) pp 30-32

MARTYNOVA, T. N. and CHAYEVSKIY, M. I., Krasnodar Polytechnical Institute

[Abstract] A general method is suggested for creation and design of miniature equal strength cylindrical composite shells which can be connected

by diffusion saturation into miniature pneumatic or hydraulic apparatus bodies. The composite shells are produced by winding tungsten or molybdenum wire 0.03 to 0.1 mm in diameter around a steel frame, then connecting the structure with the other reinforcement parts and diffusion saturation in lead containing the component to be diffused (nickel, chromium, titanium, molybdenum, etc.) to combine all parts into a single unit. An analysis of the strength of the products is presented. Figure 1, references 9: 8 Russian, 1 Western.  
[178-6508]

UDC: 539.374

#### LOAD-BEARING CAPACITY OF METAL SHELLS WITH SOFT SECTORS

Kiev PROBLEMY PROCHNOSTI in Russian No 2, Feb 83 (manuscript received 20 May 81) pp 27-29

GOL'BRAYKH, L. S., MAVLYUTOV, R. R., RAPOPORT, L. D., FAKHRUTDINOV, I. Kh., and KHUSANNOV, F. Kh., Ufa Aviation Institute; Kazan' Motor Building Association

[Abstract] A study is made of axisymmetric elastic-plastic deformation of shell of revolution with varying degrees of hardening of its sectors. These differences may be caused both by natural softening of high strength alloys around welded seams and by tempering to improve the ductility of the material and increase the load-bearing capacity of the structure in the high deformation area. The shells were designed by the method of variable elasticity parameters using deformation theory. The local softening effect was studied on the example of a flange joint between a spherical base and cylindrical shell of a high pressure structure. Local induction tempering is suggested for structural medium alloy steels and martensite aging steels with rolling of the shell together with the flange in order to improve structural strength. An aging procedure is recommended for a welded joint of a shell and flange of martensite aging steel to produce a tensile strength of 1200 mN/m<sup>2</sup>. Figures 4, references 4 Russian.  
[178-6508]

## NONUNIFORM LOADING OF SHELLS BY PONDERMOTIVE FORCES

Kiev PROBLEMY PROCHNOSTI in Russian No 2, Feb 83 (manuscript received 17 Sep 81) pp 24-26

ANDREYEV, I. V., ANTSIFEROV, A. V., VERBONOL', V. M., LEBEDEV, A. G., and PAVLENKO, I. D., Dnepropetrovsk University

[Abstract] The use of pondermotive forces acting on a current-conducting shell in an alternating magnetic field allows experimental creation of quasi-static and dynamic surface loads on thin shells. The force develops as a result of interaction of the external alternating magnetic field and the field of eddy currents induced in the shell material. It is possible in principle to produce nonuniform, nonconstant normal pressure on a shell by controlling the configuration, intensity and nature of change of the external field, as well as the distribution of total conductivity of the shell over its surface. An external magnetic field was excited by a device containing a cylindrical solenoid, capacitor, ignitron and power supply. The force of interaction of the shell with the magnetic field was controlled by local variation of conductivity by partial copper plating of the surface by galvanic precipitation of the copper through screens of varying slot width. The method can be used for creation of both dynamic and quasistatic transverse loadings. Figures 6, references 8 Russian.  
[178-6508]

## TESTING AND MATERIALS

UDC: 539.375

### PROBLEM OF THERMAL FAILURE WITH RAPID HEATING

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA in Russian  
No 1, Jan-Feb 83 (manuscript received 13 Feb 81) pp 128-135

SHESTERIKOV, S. A. and YUMASHEVA, M. A., Moscow

[Abstract] A beam in an unstressed state is studied assuming that a temperature different from the initial temperature is instantly created over the entire surface of the beam on one side, after which the temperature is maintained constant by an external source. It is found that the time to thermal fracture may be equal to or even greater than the time over which heat is applied to the beam. The process of fracture is studied assuming that the material is ideally elastic-brittle. The estimates found for the time to fracture practically coincide with experimental data. More precise consideration of the entire process of heating, melting and cooling of the specimen might make slightly more accurate results possible, but would complicate the solution by an order of magnitude. Figures 6, references 3 Russian.

[169-6508]

UDC: 662.997:537.22(088.8)

### DEVELOPMENT AND STUDY OF THERMALLY STABLE DIFFUSION-REFLECTING COATINGS

Tashkent GELIOTEKHNIKA in Russian No 2, Feb 83 (manuscript received 30 Apr 82) pp 43-45

ISMANZHANOV, A., AL'TMAN, Ts. M. and DUBROVSKIY, L. A., Central Planning-Design and Technological Bureau of Scientific Instrument Building, UzSSR Academy of Sciences

[Abstract] Diffusion-reflecting coatings have been developed for optical instruments. However, coatings developed to date are not thermally stable. The authors have tested high temperature sputtering of a metal (copper) onto a metal substrate as a means of producing a thermally stable coating, but found that the reflection was unsatisfactory. The most promising method is

manufacture and application of paints containing materials yielding high  $R_d$  fillers, with thermally stable binders. An organosilicon resin type MSN-7 was selected as the binder, with oxides of aluminum and magnesium, and chalk as fillers. Testing at high temperatures showed that the reflectivity of the chalk-based coatings remained practically constant up to 250°C, but they cracked at over 300°C. Coatings with aluminum and magnesium oxide fillers were found to be most thermally stable. Figures 3, references 3 Russian.  
[186-6508]

UDC: [535.24+535.511](045)

SCANNING POLARIZATION PHOTOMETRY -- NEW METHOD FOR DETERMINING CHARACTERISTICS OF TOPOLOGIC STRUCTURES IN MICROELECTRONICS

Leningrad OPTIKO-MEKHANICHESKAY PROMYSHLENNOST' in Russian No 3, Mar 83  
(manuscript received 7 Dec 81) pp 59-60

DANILOV, A. A.

[Abstract] A method has been developed for determining the characteristics of topologic structures, called the method of scanning polarization photometry. A diagram of a laser scanning device is presented. The beam of light from the laser is divided into two beams A and B and strikes a rotating mirror prism which causes the light to scan. One beam scans the surface of the object, then passes through a system of mirrors and focusing lenses to a photosensor. The second beam B passes through an optical grid and lens to strike the photosensor of a system for discrete recording of the coordinates of the scanned surface. Superposition of the signals from the two photosensors in the recording device correlates the coordinates with the parameters of the surface scanned. The signal returned by metal is some 20 times higher in amplitude than that returned by the dielectric surface. Scanning of the surface of a plate with a focused beam of linearly polarized light produces a sharp change in the probing signal upon transition from dielectric to metal. Figures 3, references 6: 3 Russian, 3 Western.  
[185-6508]

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